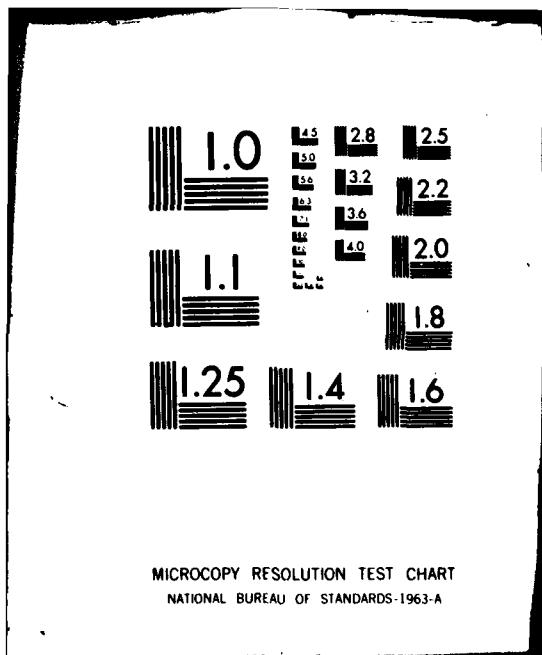


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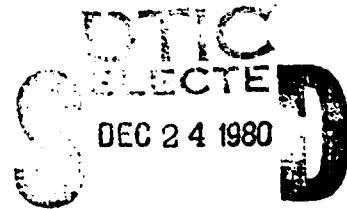
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Biological Effects of Nonionizing Electromagnetic Radiation

VOLUME V
NUMBER 1
SEPTEMBER, 1980

A DIGEST OF CURRENT LITERATURE

A Quarterly Publication Produced for
National Telecommunications and Information Administration



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**BIOLOGICAL EFFECTS
OF NONIONIZING ELECTROMAGNETIC RADIATION**

A Digest of Current Literature

**A Quarterly Publication Produced for
National Telecommunications and Information Administration**

*Literature Selected and Abstracted
by
Biomedical Group, Science Information Services Organization*

Bruce H. Kleinstein, Ph.D., J.D., Project Manager

Sheryl A. Dyner, Managing Editor

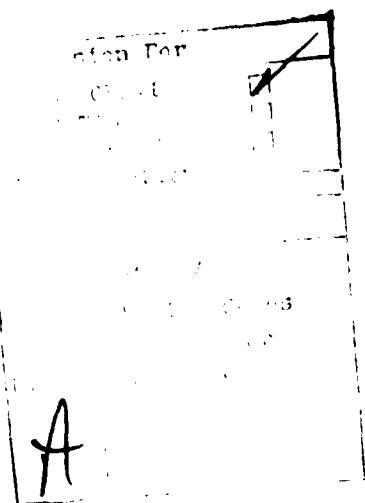
"The views and conclusions contained in this documentation are those of the author and should not be interpreted as necessarily representing the officials' policies, either expressed or implied, of the National Telecommunications and Information Administration."

BIOLOGICAL EFFECTS OF NONIONIZING ELECTROMAGNETIC RADIATION

September, 1980 Volume V, Number 1

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PREFACE

Biological Effects of Nonionizing Electromagnetic Radiation is a publication researched and prepared by the Franklin Research Center, Science Information Services Organization, under contract to and funded by the National Telecommunications and Information Administration (NTIA).

This digest serves as a vehicle through which current documentation of research highlights on the biological effects and health implications of nonionizing electromagnetic radiation (microwave and other radio frequency radiation) are compiled, condensed, and disseminated on a regular basis. *Biological Effects of Nonionizing Electromagnetic Radiation* is intended to be a highly useful current awareness tool for scientists engaged in research or related activities. The great number and diversity of relevant publications make imperative the availability of the service to persons whose work requires that they keep abreast of current developments in the field.

Biological Effects of Nonionizing Electromagnetic Radiation is published quarterly. The issues of Volume V, and future volumes, will include materials received during the preceding three months. Each issue will include news items and announcements, a listing of meetings and conferences, abstracts of current literature, and a directory of current research. Materials for which full text is not available will be included as summary abstracts.

ABBREVIATIONS AND ACRONYMS

A, amp - ampere(s)
Å - angstrom(s)
BRH - Bureau of Radiological Health
C - centigrade
cm - centimeter(s)
cps - cycles per second
dB - decibel(s)
EPA - Environmental Protection Agency
FDA - Food and Drug Administration
g - gram(s)
G - Gauss
GHz - gigahertz
HEW - Health, Education, and Welfare
hr - hour
Hz - hertz
IEEE - Institute of Electronic and
Electrical Engineers
IMPI - International Microwave Power
Institute
IU - international unit(s)
J - joule(s)
k - kilo--
l - liter(s)
m - meter(s)
m - milli--
M - mega--
mho - unit of measurement of
conductivity
min - minute(s)
mo - month(s)
n - nano--

NBS - National Bureau of Standard
NIH - National Institutes of Health
NSF - National Science Foundation
NIOSH - National Institute for
Occupational Safety and
Health
NTIA - National Telecommunications
and Information Administration
NTIS - National Technical Information
Service
Oe - oersted(s)
OSHA - Occupational Safety and Health
Administration
OTP - Office of Telecommunications
Policy
PHS - Public Health Service
rad - radiation absorbed dose
R - roentgen(s)
rpm - revolutions per minute
sec - second(s)
USAFSAM - U.S. Air Force School of
Aerospace Medicine
USDA - U.S. Department of Agriculture
UV - ultraviolet
V - volt(s)
VA - Veterans Administration
W - watt(s)
Wb - Weber(s)
WHO - World Health Organization
wk - week(s)
wt - weight
yr - year(s)

u - micro--

NEWS ITEMS

COMBINED MICROWAVE-HYPERTERMIA TECHNIQUE USED TO TREAT CANCER PATIENTS

A technique that uses microwaves to induce hyperthermia is being used with good results in cancer patients at the Henry Ford Hospital in Detroit, MI. According to Dr. Haim Bicher, head of the division of radiology and physics and a staff radiotherapist, to date 65% of 121 tumors that have been treated over the last 2 yr have shown total tumor regression. The hyperthermia is delivered in one of two ways--with an intracavitary antenna for regional hyperthermia (e.g., for the neck, mediastinum, and pelvis regions) or with applicators for external tumors. The patients are given a total of eight hyperthermia treatments over a 4-wk period. Each microwave treatment consists of hyperthermia to 117 F for 1.5 hr, 2x/wk; the last four treatments are immediately preceded by x-ray irradiation (1,600 rads) as an adjuvant therapy. The best results have been observed in patients with melanoma, lymphoma, and recurrent breast cancer on the chest wall. Skin squamous cell carcinoma, metastasizing from a lung tumor, and basal cell carcinoma have also been treated. The failures have occurred mainly with sarcomas. Dr. Bicher noted that a particular advantage of hyperthermia "is that this is the only modality used to treat cancer that does not induce cancer."

Oncology Times 2(3): 17; 1980.

HYPERTHERMIA FOR CANCER TREATMENT

The use of hyperthermia for the treatment of cancer is being studied in a number of institutions across the country. Researchers may use a variety of techniques to produce hyperthermia including radio waves, microwaves, ultrasound, and water or hot wax baths. As an experimental therapy still under investigation, hyperthermia is never used as a first line of treatment for cancer; surgery, chemotherapy, radiation, and possibly immunotherapy, are the recognized primary modalities. Since 1975, Drs. Jae Ho Kim and Eric Hahn have been doing clinical work at the Memorial Sloan-Kettering Cancer Center in New York, NY using radio frequency waves to induce hyperthermia (see Current Literature 6327, 6491). About 100 patients have been treated, most of whom, according to Dr. Kim, have been "in the more advanced stage of cancer and who have already had conventional treatment." Their treatment regimen consists of a dose of radio waves followed immediately by radiation therapy, 2x/wk for 8-10 sessions. This treatment is now being used with some success on breast cancer patients, but Dr. Kim warns that "it's too early to say if these results are permanent." Dr. F. Kristian Storm, Dr. Donald Morton, Dr. Robert Elliott, and William Harrison of the University of California-Los Angeles have also been involved with radio frequency heating since 1975 (see Current Literature 6343, 6421).

They developed a large cylinder or magnetrode that, according to Dr. Storm, provides "deep internal heating to any depth with no injury to normal tissue." The patients received ten 30- to 60-min treatments during a 2-wk period. Dr. Storm adds that when chemotherapy or radiotherapy is combined with hyperthermia, the results are "dramatic." At the Roswell Park Memorial Hospital in Buffalo, NY, microwaves are being used to create hyperthermic temperatures in tumors. Dr. Richard Johnson, a radiation oncologist, and Henry Kowal, a former Air Force engineer, have treated more than 100 patients at the hospital since 1975 (see Current Literature 6430, 6477, 6515, 6673). The treatment at frequencies of 915 MHz to 434 MHz usually consists of ionizing radiation (300-400 rads) followed by 30-90 min of microwaves (to produce temperatures of 42-42.5 C), 2x/wk. To date, results from the various hyperthermic techniques have ranged from temporary remission to "no response." Dr. Storm states that he knows "of no patient who's been 'cured' by hyperthermia," but, he adds, "in a few of his patients, survival was clearly enhanced." Most hyperthermia clinicians seem to agree with Dr. Storm, who says that "At present, hyperthermia is nothing more than an investigational therapy," but "we think that once it's understood, it may well be a fifth form of treatment for cancer."

New York Times 129(44531, Section 6): 96, 98, 100, 102, 108; March 1980.

PROFESSOR RECEIVES GRANT TO CONTINUE STUDIES OF MICROWAVE EFFECTS ON CANCER CELLS

Professor E. H. Grant of the Physics Department of Queen Elizabeth College in London, England has received a grant for 1980 of 11,728 pounds from the British Cancer Research Campaign for continued research into the effect of microwave energy on cancer cells. Two aspects of microwave hyperthermia--localized heating and accurate temperature measurement--are being studied. A miniature applicator within a hypodermic needle has been designed and two more applicators are proposed to boost the energy dissipated by the cancer tissue. The initial experiments were performed with 2.45 GHz, but the effects of varying the microwave signal frequency to obtain optimum heating will also be studied. Hospital trials may be conducted later this year or early in 1981.

Microwaves 19(5): 68; 1980.

DR. DURNEY RECEIVES RESEARCH AWARD

The University of Utah presented a Distinguished Research Award for the 1980-1981 academic year to Dr. Carl Durney. Dr. Durney, Professor and Chairman of the Department of Electrical Engineering and

NEWS ITEMS

Research and Professor of Bioengineering, received the award for his pioneering research into the medical effects of microwave radiation. The award was presented at the June 1980 graduation exercises.

Utah Bioengineering Newsletter
p. 1, Spring 1980.

STUDY SHOWS NO BIRTH DEFECTS IN RATS DUE TO NONTHERMAL MICROWAVES

Following a decade of extensive laboratory research on microwave bioeffects, Dr. Ronald P. Jensh, Ph.D. (Department of Anatomy, Thomas Jefferson University, Philadelphia, PA 19107) has found no physical or behavioral birth defects due to nonthermal microwaves. Dr. Jensh's research included one study performed on a grant by the EPA on the teratologic potential of microwaves at 915 and 2,450 MHz (see Current Literature 6258) and another study performed for the General Telephone and Electronics Corporation on the effects of a carrier frequency at 6,000 MHz. According to Dr. Jensh, associate professor of anatomy and radiology at the College of Allied Health Sciences, their "studies indicate that microwave ovens can be one of the safest appliances you can have in your kitchen," and the ovens will not harm anyone who uses them correctly. During the course of Dr. Jensh's study for the EPA, rats were exposed to microwaves 8 hr/day for 16 days during a 3-wk gestation period. The postnatal effects of prenatal exposure were studied and rats and their offspring were dissected to determine if any tissue damage occurred. Both the mothers and fetuses were healthy. When mothers were bred more than once to determine if microwave exposure affected future offspring, "Neither the first nor the second generation offspring was deformed," says Dr. Jensh. To observe subtle behavioral defects, five tests of the offsprings' ability to learn and memorize simple tasks were conducted, as well as six tests of the rats' reflexes. No abnormalities were detected.

Allied Health Rev Res Wkly (11): 9-10; 1980.

AMENDMENT TO MICROWAVE OVEN STANDARD FOR MEASUREMENT AND TESTING IS PROPOSED

The FDA has proposed to amend the performance standard for microwave ovens to delete the error limit and effective aperture requirements for instruments used for compliance measurement of leakage radiation from microwave ovens. The proposal would provide, as part of the manufacturer's testing program for microwave ovens, that periodic reports be submitted to the BRH on the characteristics of these instruments and on the conditions under which they are used. Over the past several years, FDA's

Biological Effects of Nonionizing Electromagnetic Radiation V(1), September 1980

evaluations of the characteristics and methods of calibration of many microwave survey instruments have indicated that it is possible that a commercially available instrument may produce readings of oven leakage that are in error by more than 1 db. The proposed alternate compliance policy would take into account the technical limitations associated with the measurement of microwave radiation. The BRH will have the responsibility to review testing programs by which the manufacturers certify their ovens. Under the proposal, manufacturers may use any instrument with uncertainties greater than ± 1 db in their compliance testing programs provided that the uncertainties are taken into account and that the BRH concurs with the manufacturer's stated limit of uncertainty. The FDA has determined that this proposal would not compromise microwave oven safety. The FDA has also proposed that the concept "equivalent plane-wave power density" be substituted in the existing standard for "power density" (performance standard 21 CFR, sections 1030.10 [c]1 and [c]3i) and that a definition of "equivalent plane-wave power density" (as "the square of the root-mean-square electric field strength divided by the impedance of free space [377 ohms])" be added to improve the standard's technical accuracy. The proposed amendments are designed to reflect the actual compliance test situations for microwave ovens. No change in the permissible leakage levels is to be made. For further information contact Joseph Wang, BRH (HFX-460), FDA, HEW, 5600 Fishers Lane, Rockville, MD 20857 or (301)-443-3426.

Fed Regist 45(87): 29307-29308; 1980.

NATURAL RESOURCES DEFENSE COUNCIL UNSATISFIED WITH NIOSH CRITERIA DOCUMENT ON NONIONIZING RADIATION

The Natural Resources Defense Council (NRDC; 10 East 78th Street, New York City, NY) criticized the November draft of a NIOSH criteria document on nonionizing radiation. The environmental group felt that the draft paid too little attention to low-level radiation effects. The NRDC also requested that a modified version of the draft be released as an "interim" working draft, and that the modified version recommend that OSHA adopt a "flat" exposure standard of 1 mW/cm^2 for frequencies between 0.3 MHz and 300 GHz and drop the "complex frequency dependency" in the proposed standard. A NRDC letter to Anthony Robbins, NIOSH Director, charged that the November draft paid too much attention to the thermal effects of radiation and offered "no explanation of why the proposed standard would adequately protect worker health."

Occup Saf Health Rep 9(31): 724-725; 1980.

IEC RELEASES INTERIM REPORT ON WORLDWIDE RADIATION STANDARDS

The International Electrotechnical Commission (IEC; Geneva, Switzerland) has released an

interim report, Publication No. 657, that summarizes the present limits and attitudes towards nonionizing hazards that have been adopted by a number of countries, the IEC, and other international agencies. The report emphasizes that there is still no worldwide consensus on what levels of nonionizing radio frequency radiation constitute a hazard to man and calls for further work at the national level. The origin of some of the differences between the national standards are reviewed and discussed. Some preliminary conclusions are drawn. It is suggested that when considering standards for maximum allowable levels of nonionizing radiation, it is important to distinguish between personnel safety limits and equipment specifications. The study suggests, that if there was worldwide agreement on personnel exposure limits, then there would be no great difficulty in deriving appropriate specification limits for the various classes of equipment.

Microwaves 19(4): 30; 1980.

**DETAILED RESEARCH PROGRAM ON BIOLOGIC
EFFECTS OF HIGH-VOLTAGE POWER LINES
REQUESTED BY THE NEW YORK
PUBLIC SERVICE COMMISSION**

Following an extensive public hearing on the health and safety effects of high-voltage power lines, negotiations have been concluded for the initiation of a "detailed" research program on the biologic effects of the lines' 60-Hz electric and magnetic fields. The 5-million dollar program will be designed and administered jointly by three New York state agencies: Public Service Commission, Department of Health, and the Power Authority. Requests for proposals for research efforts are expected to be issued around January 1981. The aim of the program will be to determine as precisely as possible what health risks might be suffered by people who live and work along a high-voltage right-of-way. Negotiations on the research program follow a 3-yr Public Commission hearing on the Authority's 765-KV line, which stretches 155 miles from the Quebec border to Utica, NY. After evaluating the evidence presented at the hearing, the Commission decided that the fields did constitute a health risk and ordered the Authority to expand its right-of-way by 100 feet and forbade operation of the line until the Authority promised to contribute 2% of its construction costs to a research program. The authority contested the order in court, and began operating the line, despite opposition by residents who had opposed the line's construction. In court, the Commission's original decision on the biologic effects was upheld, but the order for the Power Authority to fund a research program was overturned. Following the court's decision, the Commission filed an appeal to a higher court on the latter decision. The present negotiations are apparently the result of the Power Authority's failure to answer the appeal. Although the details are not finalized, the research program may consist of both laboratory and epidemiologic studies and will most likely be supervised

by a panel of independent scientific experts. If the Commission determines after the research is complete that human exposure limits to 60-Hz electromagnetic fields should be even stricter, it will have the authority to impose regulations enforcing these limits, not only on 765-KV lines but on smaller ones as well.

Bull At Sci 36(4): 28-30; 1980.

**FIRST CALL FOR PAPERS FOR 1981 IEEE/MTT-S
INTERNATIONAL MICROWAVE SYMPOSIUM
ANNOUNCED**

The Institute for Electrical and Electronics Engineers (IEEE)/Microwave Theory and Techniques Society (MTT-S) has announced the first call for papers for their 1981 International Microwave Symposium to be held June 15-17 in Los Angeles, CA. The theme for the 1981 Symposium is "Around the World with Microwaves." The Symposium will be held jointly with the IEEE Antennas and Propagation Symposium that will meet June 17-19. Papers describing original work, which have never been published or presented, are solicited. Papers concerned with new techniques, devices, systems, applications, and bioeffects will be considered. Authors should submit both a 35-word abstract and a 500-1,000 word summary (up to 6 illustrations) explaining their contribution, its originality, and relative importance. Abstracts and summaries (5 copies) should be received by Dr. Don Parker, TPC 1981 MTT-S Symposium, Hughes Aircraft Co., Building 268/Mail Station A54, Canoga Park, CA 91304 by January 15, 1981.

IEEE/MTT-S Announcement.

**MAGNETIC ORIENTATION IN BIOLOGY
DISCUSSED AT THE 18th INTERNATIONAL
INTERMAG CONFERENCE**

The 18th International Intermagnetics Conference was held April 21-24, 1980 in Boston, MA. Session 25 of the Conference was concerned with magnetic orientation in organisms. Four papers were presented that summarized recent work on the ability of organisms to sense the earth's magnetic field and use it for orientation and migration. A. J. Kalmijn reviewed electroreception in sharks and skates and magnetotaxis based on ferromagnetic alignment in bacteria. R. P. Blakemore and C. Denham comprehensively reviewed bacterial magnetotaxis. Blakemore discussed his expedition to New Zealand where south-swimming magnetotactic bacteria were found, and Denham presented magnetic data on whole cells and cellular components that identified magnetosome as the site for the biomagnetic compass of these cells. For the third presentation, C. Walcott reviewed the evidence that suggests that pigeons use the earth's magnetic field in their homing behavior. The evidence suggests that pigeons may use their magnetic sense(s) both as a compass and as a map, and it was reported that magnetite has been detected in the heads of pigeons. The

NEWS ITEMS

fourth presentation on magnetic orientation in biology was J. L. Kirschvink's review of evidence concerning the honey bees' sensitivity to the earth's magnetic field. Magnetite has also been detected in the abdomens of bees.

IEEE Magnetics Society Newsletter
16(1): 3; 1980.

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sible changes in the body regulatory mechanism caused by drug and radiation combination, but interest in studying the longer term effects of low doses of microwave radiation is growing. A program is scheduled at the University of Washington to study the behavior of rats exposed to microwave radiation over a period of years.

Electronics 53(7): 46; 1980.

BATTELLE LAB STUDYING THE EFFECTS OF MICROWAVES AND TRANQUILIZERS

A two-part study is being conducted at Battelle's Pacific Northwest Laboratory to determine if microwaves enhance the effect of tranquilizers and if they have any affect on learning. According to Dr. Richard Lovely, a senior research scientist at Battelle's Biology Department, "Recent studies using laboratory rodents suggest that microwaves may intensify the effects of chlorodiazepoxide, one of the most widely prescribed tranquilizers in the country. Other preliminary findings suggest that microwave exposure has an adverse effect on the brain's ability to memorize complex or sequential tasks." Battelle's study is specifically investigating the higher levels of microwave radiation (as opposed to lower levels emitted from microwave ovens, etc.) and the workers who may be exposed to them.

Ind Res Rev 22(6): 39; 1980.

RESEARCH SUGGESTS POSSIBLE NONTHERMAL EFFECTS FROM LOW-LEVEL MICROWAVE EXPOSURE IN ANIMALS

Research conducted at the John B. Pierce Foundation, New Haven, CT and the University of Rochester, Rochester, NY has suggested that low levels of microwave radiation may produce interference with the body's mechanism for regulating internal temperatures. At the Pierce Foundation, squirrel monkeys trained to regulate their cage temperature lowered the temperature after 10 min of exposure to 2.45-GHz continuous-wave (CW) radiation of incident power density 6-8 mW/cm². Their body temperatures, however, did not change until the power density was 22 mW/cm². Similar results were reported at the University of Rochester for experiments with rats. Another study at Pierce demonstrated measurable tail vein dilation in irradiated (2.45-GHz CW radiation at 10 mW/cm²) monkeys without any change in the deep body temperature. Experiments conducted at the Naval Medical Research Institute in Bethesda, MD have demonstrated that the stimulating effect of dexadrine amphetamine in rats increases greatly at dosages of irradiation as low as 1 mW/cm². This work follows tests in which Librium produced odd behavioral effects in rats irradiated at 2.45 GHz. The Navy researchers are not speculating on pos-

ELECTROTHERAPY USED TO STIMULATE BONE GROWTH

Dr. C. Andrew L. Bassett, professor of orthopedic surgery at Columbia University's College of Physicians and Surgeons, New York, has developed a non-invasive system for stimulating bone growth. The technique involves a 10-V pulse generator that drives current through externally mounted, "0"-shaped wire coils, setting up an electromagnetic field of 2 G between the coils over the nonunion site. Bassett's device, which has received pre-market approval by the FDA, sells for about \$2,000. The device, which has been used in more than 1,500 patients, has an 80% success rate for healing non-union fractures in adults. It can be used to treat fractures all over the body, although the majority of cases involved the tibia. Aside from its obvious advantage--noninvasiveness--the device is also able to precisely deliver current to area of the nonunion. The precision, and subsequent bone healing, depends on the accurate placement of the external coils. "The placement of the coils must be done under x-ray control..." says Dr. Bassett, and adds that "... the orthopedic surgeon is absolutely critical in this whole business." He agrees that electrical bone growth stimulation has not and probably will never replace bone grafting as a method for treating some cases, e.g., synovial pseudoarthroses, serious infections, and bone gaps greater than one-half the bone diameter; however, an advantage of Bassett's electrotherapy technique is that it appears to work well in combination with bone grafting surgery.

JAMA 243(14): 1402-1403; 1980.

ELECTROMAGNETIC DEVICE DETERMINES DEGREE OF SKIN BURN

A device that uses electromagnetic fields (wavelength 0.7-1.1 cm) at current density of 100 μ W/cm² to analyze the degree of human skin thermal damage was patented. The degree of burn is determined by comparing the characteristics of healthy and damaged skin after irradiation with an electromagnetic field. The reflected signal power is measured, the reflection coefficient is determined, and the damage degree is determined according to the coefficient value.

Sov Invent Illustr C18(SU-P3): 2; 1980.

**ELECTROMAGNETIC TREATMENT FOR
NECK BONE CARTILAGE IS DESIGNED**

A method for the application of decimeter electromagnetic waves followed by sinusoidally modulated currents for the treatment of neck osteochondrosis has been designed. The electromagnetic waves are applied for 8-10 min and followed within 5-10 min by the sinusoid currents, frequency 80-100 Hz and current intensity 10-50 mA.

Sov Invent Illust C09(Su-P3): 6; 1980.

**DISINFECTION OF EGGS
BY AN ELECTROMAGNETIC FIELD**

A method for disinfecting eggs in a high-frequency electromagnetic field has been designed. The technique employs an amplitude modulated electromagnetic field with a carrier frequency of $1.0-1.2 \times 10^9$ Hz and an electrical field strength of 200-250 V/cm or a modulated field with a frequency of $1.0-1.5 \times 10^7$ Hz and a field strength of 150-200 V/cm. Treatment with the modulated field is periodic; the duty factor is 10-100 and the interval is 0.1-1 sec. The total treatment takes 1-4 hr. For example, the temperatures of hens' eggs that have been placed between the flat electrodes of the electromagnetic field source are increased over 8 min to 52.4 °C at the shells' surface and 43.0 °C inside the eggs. The eggs remain at this temperature for 2.5 hr. The temperatures at the shell and within the egg are controlled by heat resistors to an accuracy of 0.01 °C. The characteristics of the field and shape of the voltage curve are controlled by an oscilloscope, pulse voltmeter, and multimeter. Biologic tests demonstrate that contaminating microflora were absent after treatment, while the embryos continued to develop and grow. This technique increases the effectiveness and reduces the time necessary for egg disinfection.

Sov Invent Illust B47(SU-D): 5; 1980.

39th ERMAC MEETING HELD

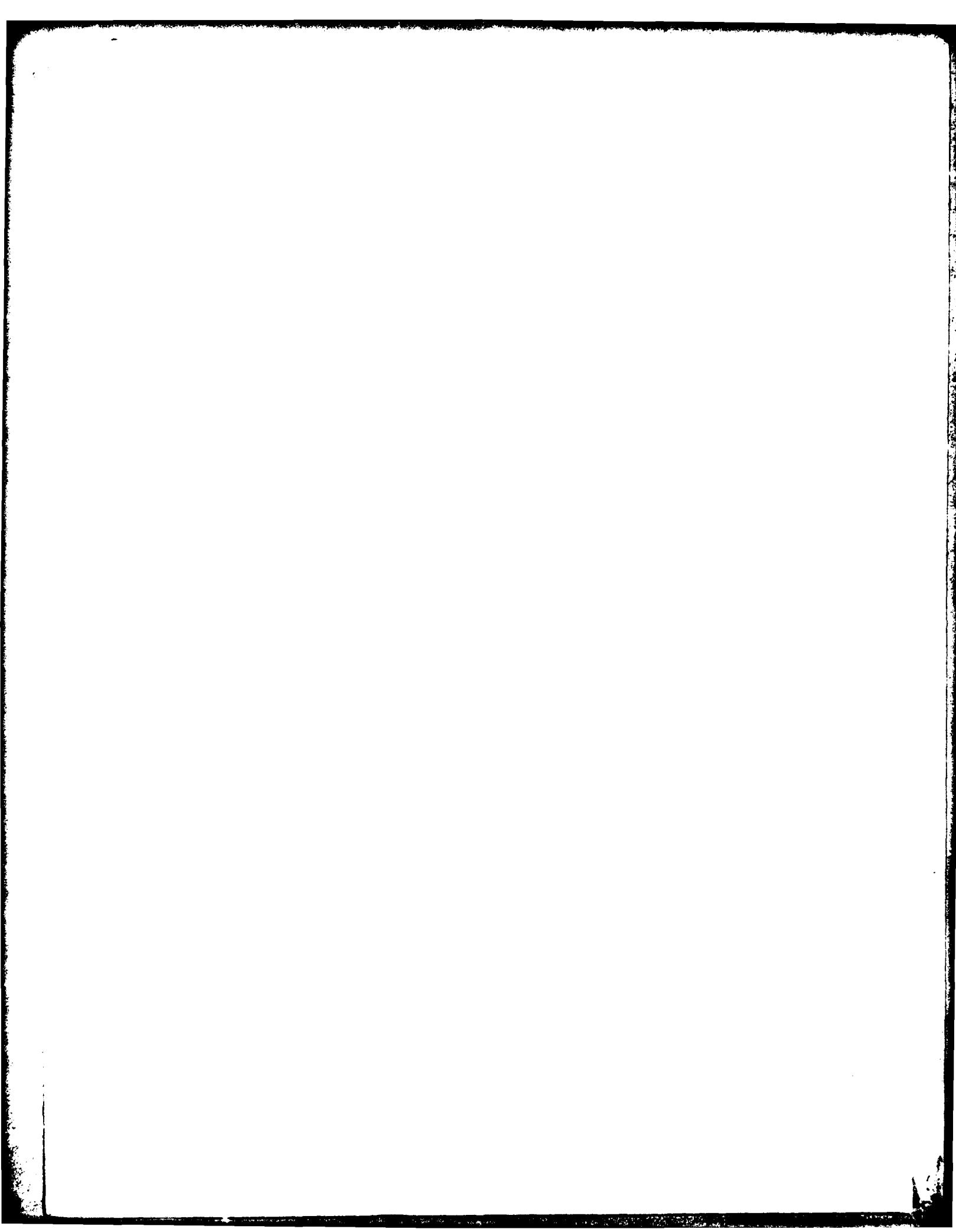
The 39th meeting of the Electromagnetic Radiation Management Advisory Council (ERMAC) was held August 26-27, 1980 in Washington, DC. The meeting, sponsored by the NTIA, was basically concerned with two topics--the biologic implications resulting from the Soviet irradiation of the U.S. Embassy in Moscow and the scientific basis for microwave and other radio frequency radiation standards. The session concerned with the microwave irradiation of the U.S. Embassy included presentations and discussions on the analysis of the microwave environment, its biologic implications, and report strategy and contents. The sessions concerned with the scientific basis for standards included presentations and discussions on the specific absorption rate concept, physical and mathematical modeling, selection and scaling of key experiments to humans, modeling and selection of data, and the possible mechanisms for the observed effects. Copies of the minutes of the meeting will be available from NTIA.

ERMAC 39th Meeting--Revised Agenda.

ITEMS FROM THE COMMERCE BUSINESS DAILY

**THEORETICAL RESEARCH STUDY TO
DETERMINE THE EFFECTS OF HIGH POWER
MICROWAVE RADIATION ON MATERIALS.**

The Office of Naval Research, 800 N. Quincy St., Arlington, VA 22217 is negotiating with the Scientific Research Center, 1640 Fifth St., Santa Monica, CA 90401 for the above study. (June 2, 1980)



MEETINGS AND CONFERENCES

BIOELECTROMAGNETICS SOCIETY SECOND ANNUAL MEETING

Date: September 14-18, 1980
Place: San Antonio, TX: El Tropicano Hotel
Sponsor: Bioelectromagnetics Society
Requests for Information: Bioelectromagnetics Society, P.O. Box 3651, Arlington, VA 22203
Content: Topics will cover the interaction of electromagnetic energy and acoustic energy with biologic systems, including behavioral, physiologic, neurologic, endocrine, developmental, genetic, and cellular and ultrastructural effects. Also included are the dielectric properties of biologic materials, electric field effects, exposure systems, dosimetry, diagnostic and therapeutic applications, interactive mechanisms, instrumentation, hyperthermia, and field perturbations

INTERNATIONAL CONFERENCE ON ELECTROMAGNETIC COMPATIBILITY

Date: September 16-18, 1980
Place: Southampton, England: University Southampton
Sponsor: Institution Electronic and Radio Engineers, Institution Electronical Engineers, Institute Electrical and Electronics Engineers, Institute Marine Engineers, Institute Quality Assurance, Royal Aero-nautic Society
Requests for Information: Conference Registrar, Institution Electronic and Radio Engineers, 99 Gower St., London WC1E 6AZ, England

Selected Bibliography of Papers to be Presented:

AN EM ENVIRONMENT FOR AIRCRAFT--PREDICTION OF FIELD STRENGTH NEAR HF TRANSMITTERS. P. J. Frank, J. M. Thomson

ESTIMATING BULK SURFACE CURRENT OF FAT CYLINDERS DUE TO AN EMP. J. Bishop

INVESTIGATION OF SOME RF RADIATION HAZARD METERS. I. Langlet

RF INTERFERENCE GENERATED BY A THYRISTOR CONTROLLED HAND-HELD DRILL MOTOR. J. K. Hall, M. W. Quelch

FIFTH INTERNATIONAL WROCLAW SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY

Date: September 17-19, 1980
Place: Wroclaw, Poland: Wroclaw Technical University
Sponsor: Association Polish Engineers, Wroclaw Technical University, Institute Telecommunications, Polish Academy Sciences, International Union Radio Science (URSI), International Electrotechnical Commission (IEC)
Requests for Information: W. Moron, Symposium Secretary General, EMC Symposium, 51-645 Wroclaw 12, Poland

Selected Bibliography of Papers to be Presented:

MICROWAVE ON-LINE MOISTURE CONTENT MONITORING IN LOW-HYDRATED ORGANIC MATERIALS. S. Kulinski, K. Zielkowski, J. Madziar, A. Kraszewski

POSSIBILITIES OF MICROWAVE HEATING. S. Lefevre

MICROWAVE THERMOGRAPHY--THE MODELLING OF PROBES. AN APPROACH TOWARD THERMAL PATTERN ROGNITION. D. D. N'Guyen, M. Robillard, M. Chive, Y. Leroy, J. Audet, Ch. Pichot, J. Ch. Bolomey

NUMERICAL SIMULATION AND MODELS FOR MICROCOAXIAL STROBES, APPLICATION TO "IN VIVO" MEASUREMENTS OF DIELECTRIC PARAMETERS OF BIOLOGICAL MEDIA IN THE MICROWAVE BAND 1-12 GHz. F. Bliot, A. Castelain, B. Dujardin

MICROWAVE HEATING OF REALISTIC CYLINDRICAL MODELS OF HUMAN LIMBS. H. Tosun, I. Karayilan

33rd ANNUAL CONFERENCE ON ENGINEERING IN MEDICINE AND BIOLOGY

Date: September 30-October 3, 1980
Place: Washington, DC: Washington Hilton Hotel
Sponsor: Alliance for Engineering in Medicine and Biology, Institute Electrical and Electronics Engineers (IEEE) Engineering in Medicine and Biology Society
Requests for Information: Alliance for Engineering in Medicine and Biology, 4405 East-West Highway, Washington, DC 20014

Selected Bibliography of Papers to be Presented:

SHORT COURSE 1--RADIOFREQUENCY AND MICROWAVE THERMOTHERAPY IN THE TREATMENT OF CANCER. A. Y. Cheung, D. R. Justesen, M. Salzman, G. M. Samaras, R. M. Scott, M. A. Stuchly, S. S. Stuchly

UTILITY ELF ELECTRIC FIELD MEASURES FOR BIOPHYSICAL STUDIES. O. H. Schmitt, R. D. Tucker, J. E. Holte

NONINVASIVE ANKLE BLOOD PRESSURE MEASUREMENTS. S. X. Salles-Cunha, N. Wynn, D. Vincent, K. D. Vollrath, H. D. Itsikovitz

UNDERWATER ELECTRIC FIELDS CONTROL MOVEMENTS OF MIGRATORY FISH. R. B. Northrop

HAZARDS OF ELECTROSURGICAL DEVICES--SOME CASE REPORTS. F. S. Osman, D. L. Johnson

A MICROWAVE DEVICE FOR ARTERIAL WALL MOTION ANALYSIS. S. S. Stuchly, A. Smith, M. Goldberg, A. Thansandote, A. Menard

A VARIABLE FREQUENCY MICROWAVE SYSTEM FOR HYPERHERMIA. D. E. Cunningham, R. A. Frey, D. E. Velkey

MEASUREMENTS OF MAGNETIC FIELD OF ISOLATED NERVES. J. P. Wikswo

MEDICAL COMPUTED TOMOGRAPHY USING MICROWAVES. P. M. Forques, M. Goldberg, A. Smith, S. S. Stuchly

MEETINGS AND CONFERENCES

1980 IEEE INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY

Date: October 7-9, 1980
Place: Baltimore, MD: Baltimore Hilton Hotel, 101 West Fayette St.
Sponsor: Institute Electronics and Electrical Engineers
Requests for Information: IEEE EMC '80 Symposium, P.O. Box 1711, Annapolis, MD 21404

Selected Bibliography of Papers to be Presented:

RF AND MICROWAVE EMISSIONS FROM A VIDEO DISPLAY TERMINAL, COLOR TV RECEIVER, AND A MONOCHROME TV RECEIVER. A. A. Smith

ANALYSIS OF AIRBORNE RF MEASUREMENTS FROM USA URBAN AREAS. R. E. Taylor, J. Hill

NEW AND KNOWN METHODS OF THE APPLICATION OF TRANSFORMS TO QUASIPERIODIC BIOMEDICAL SIGNALS. B. Meffert, D. Schubert, T. Lazarus, R. Poll

MOBILE DATA COMMUNICATION RELEVANT TO SAFETY. G. H. Schildt

A SYSTEM PERFORMANCE CRITERION FOR COMPARING ELECTROMAGNETIC ENVIRONMENTAL EFFECTS. M. L. Van Blaricum, A. R. Hunt

A PRACTICAL APPROACH TO ESTABLISH EFFECTIVE GROUNDING FOR PERSONNEL PROTECTION. C. C. Kleronomos, E. C. Cantwell

AN EMC TEST PROCEDURE FOR AN ELECTROENCEPHALOGRAPHY (EEG) USING HUMAN SUBJECTS AND SIMULATED PATIENTS. P. S. Ruggera

FIFTH INTERNATIONAL CONFERENCE ON INFRARED AND MILLIMETER WAVES

Date: December 8-12, 1980
Place: Wurzburg, West Germany
Sponsor: Institute Electrical and Electronics Engineers (IEEE)/Microwave Theory and Techniques Society
Requests for Information: K. J. Button, MIT National Magnetic Laboratory, Cambridge, MA 02139
Content: Sessions will cover the biologic effects of electromagnetic radiation

FOURTH INTERNATIONAL ELECTROMAGNETIC COMPATIBILITY SYMPOSIUM

Date: March 10-12, 1981
Place: Zurich, Switzerland: Federal Institute Technology
Sponsor: Association Swiss Electrotechnicians
Requests for Information: Dr. T. Dvorak, ETH Zentrum-KT, 8092 Zurich, Switzerland
Content: Topics will cover the protection of the electromagnetic environment and will include the social and economical impact of electromagnetic compatibility (EMC); electromagnetic pollution, control, and enforcement; national and international cooperation in EMC; immunity of electronic systems;

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EMC of communications, electric power, and automation; EMC hazards to vital safety systems; compatibility of medical electronics; biologic effects of radio frequency energy; and shielding and absorptive materials

19th INTERNATIONAL MAGNETICS CONFERENCE

Date: May 12-15, 1981
Place: Grenoble, France
Sponsor: Magnetics Society/Institute Electrical and Electronics Engineers, Societe Francaise de Physique, Societe des Electroniciens et des Radioelectriques
Requests for Information: James M. Lommel, General Chairman, General Electric Company, Corporate R&D, P.O. Box 8, Schenectady, NY 12301
Content: Topics will cover new developments in applied magnetics and related magnetic phenomena, including magnetics in the life sciences

1981 IEEE/MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM

Date: June 15-17, 1981
Place: Los Angeles, CA: Bonaventure Hotel
Sponsor: Institute Electrical and Electronics Engineers (IEEE)/Microwave Theory and Techniques Society (MTT-S)
Requests for Information: Al Clavin, Chairman, Hughes Aircraft Co., Building 268/A-55, Canoga Park, CA 91304
Content: Topics will include microwave techniques, devices, systems, applications, and bioeffects

TENTH L. H. GRAY CONFERENCE

Date: July 13-16, 1981
Place: Oxford, England
Sponsor: Institute Cancer Research
Requests for Information: Dr. R. C. Hill, Institute Cancer Research, Royal Marsden Hospital, Sutton, Surrey, England
Content: The biology and biophysics of radio frequency, microwave, and ultrasonic radiation will be reviewed, particularly with respect to their potential therapeutic value

URSI 20th GENERAL ASSEMBLY

Date: August 10-19, 1981
Place: Washington, DC: Hyatt Regency Hotel, 400 New Jersey Ave., NW
Sponsor: International Union Radio Science (URSI)
Requests for Information: Mr. R. Y. Dow, National Academy Sciences, 2101 Constitution Ave., NW, Washington, DC 20418
Content: Topics will cover the branches of radio science including electromagnetic metrology, such as radio standards, and interactions between electromagnetic radiation and biologic systems. A 2-day series on interactions of electromagnetic waves with biologic systems will include a) two traditional summary and review sessions on the physical and biologic aspects and on significant advances and trends in this field and b) two physical interaction mechanisms

CURRENT RESEARCH

0618 **IMPLANTABLE MICROWAVE APPLICATORS.** Taylor, L. S. (Dept. Electrical Engineering, Sch. Engineering, Univ. Maryland, College Park Campus, College Park, MD 20742).

Small implantable applicators in the form of hypodermic needles are being developed that can be inserted into tissue or into miniature flexible radiating cables that can then be inserted into body cavities. The potentials and characteristics of modified sleeve and colinear array radiators, magnetic radiators, and cylindrical and coaxial waveguide radiators are being evaluated and compared. (funding period 11/79-4/82)

Supporting Agency: NSF, Directorate for Engineering and Applied Science, Div. Electrical Computer and Systems Engineering

0619 **MICROWAVE-INDUCED MECHANICAL RESONANCES IN BIOLOGICAL SYSTEMS.** Olsen, R. G.; Grisgett, J. D. (Medical Sciences Dept., Naval Aerospace Medical Res. Lab., Navy, U.S. Dept. Defense, Pensacola, FL 32508).

The effects of pulsed or modulated microwave energy on biologic systems will be studied, with regards to the mechanical waves produced thermoelastically by the irradiation. The microwave-induced mechanical waves will be evaluated empirically in man. In addition, the impact of any of the observed effects on the relative hazard potential of various types of Navy transmitting systems will be assessed. Pulsed and amplitude modulated microwave energy from 1 to 10 GHz will be beamed at brain, bone, and muscle models that have been instrumented with sensitive transducers to record the excitation of vibrational modes. The observed mechanical waves produced in the models will be compared to theoretical predictions of resonant frequencies, and attempts will be made to stimulate the mechanical vibrations within the samples by modulating or pulsing the microwave energy at the observed resonant frequencies. The microwave carrier frequency and intensity will be chosen for each model to produce an electromagnetic absorption of sufficient magnitude and optimal spatial pattern to elicit a vigorous thermoelastic response. (funding period 10/78-9/81)

Supporting Agency: U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command, Natl. Naval Medical Center

0620 **EPIDEMIOLOGY OF MAGNETIC EFFECTS ON HUMANS.** Budinger, T. F. (Lawrence Berkeley

Lab., Univ. California, Berkeley Campus, Berkeley, CA 94720).

The possible effects of the stationary and alternating magnetic and electric fields produced by controlled thermonuclear reactors, high-voltage transmission lines, magnetic energy storage systems, and magnetohydrodynamic systems are being investigated. Data will be analyzed from an epidemiologic study of 2,000 scientists and technicians who have been exposed to high fields for substantial cumulative exposures. (funding period 0/79-n/a)

Supporting Agency: U.S. Dept. Energy, Office Health and Environmental Res.

0621 **BIOLOGICAL EFFECTS OF HIGH MAGNETIC FIELDS.** Tenforde, T. S. (Lawrence Berkeley Lab., Univ. California, Berkeley Campus, Berkeley, CA 94720).

Biomagnetic effects are being investigated to provide quantitative baseline data for the establishment of exposure guidelines for workers in energy-related technologies that utilize stationary and pulsed direct current (dc) fields. Magnetic field effects are being evaluated from physiologic measurements in small mammals, including body temperature, cardiac activity, respiration, blood and urine composition, hormones, hematopoiesis, tissue pathology, and neurobehavioral parameters. Biomagnetic effects in potentially sensitive neural and visual tissues are being assessed by electrophysiologic techniques. Development of organisms in strong fields is being studied with model insect and plant systems. After fabrication of a suitable large-volume magnet, functional studies will be carried out on the visual, cardiovascular, respiratory, and nervous systems of exposed individuals. These studies will provide a comprehensive assessment under well-controlled experimental conditions of biomagnetic effects in mammalian systems. This data will be directly relevant to the establishment of occupational exposure guidelines at fusion reactor facilities, magnetohydrodynamic systems, magnetic energy storage systems, isotope separation facilities, cyclotrons and bubble chambers, and technologies that involve induction-type devices such as induction welding. (funding period n/a)

Supporting Agency: U.S. Dept. Energy, Office Health and Environmental Res.

0622 **EFFECT OF MICROWAVES FROM NAVY RADAR ON VARIOUS CELL TYPES WITHIN THE IMMUNE SYS-**

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TEM. Smith, A.; Jedrejczak, W. W. (Sch. Medicine, Georgetown Univ., 3800 Reservoir Rd., NW, Washington, DC 20007).

The effect of microwaves on the immune system will be investigated in inbred mice strains. Microwave exposures will be carried out in a recently constructed waveguide facility. The first study will attempt to repeat some previous research in which an increase was found in the proportion of lymphoid cells bearing a receptor for complement (CR+) in the spleen. In addition, the establishment of the threshold for this phenomenon will be attempted. Kinetic studies will be carried out to determine the most appropriate latent time for assay following the microwave exposure. Finally, the effects of multiple, subthreshold exposures will be studied to determine if such exposures are cumulative. (funding period 3/78-n/a)

Supporting Agency:U.S. Dept. Defense: Navy, Office Naval Res.

The interaction mechanisms responsible for low-level microwave-induced changes in membrane permeability of the blood-brain barrier will be investigated, with particular attention paid to the role of modulation and temperature. Radioisotope methods will be employed to monitor the membrane transport properties of mammalian cells exposed to microwave radiation. Studies will be carried out systematically to determine the exact dependence of any observed permeability changes on modulation and temperature. To further elucidate the interaction mechanisms responsible for any observed permeability changes, dynamic measurements will be used to monitor structural changes that occur in the biologic membrane and its environment during a single microwave pulse. These data will be helpful in identifying the mechanism of interaction of the microwave field with the biologic membrane. The transport data taken together with the dynamic measurements should identify thresholds for any observed effects. (funding period 10/77-9/82)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command, Natl. Naval Medical Center

0623 EFFECTS OF RADIOFREQUENCY RADIATION (RFR) ON BIOLOGIC MEMBRANES. Dowben, R. M.; Matthews, L. (Dept. Pathology, Sch. Medicine, Baylor Coll. Medicine, 1200 Moursund Ave., Houston, TX 77025).

Unique, state-of-the-art experimental techniques will be used to evaluate membrane structure and function in rodents after whole-body exposure to pulsed radio frequency radiation. The following parameters will be studied: 1) membrane protein composition as analyzed by two-dimensional polyacrylamide gel electrophoresis using novel detergents; 2) membrane fluidity, lateral mobility of membrane proteins, and transmembrane potential as measured by unique fluorescent probes and a one-of-a-kind time-correlated laser fluorimeter; and 3) membrane ultrastructure as revealed by cross-sectional and scanning electron microscopy. (funding period 10/79-4/81)

Supporting Agency:U.S. Dept. Defense: Air Force, Sch. Aerospace Medicine, Brooks Air Force Base

0625 ELECTROMAGNETIC FIELD EFFECTS ON THE CELL MEMBRANE. Marron, M. T.; Goodman, E. M.; Greenebaum, B. (Dept. Chemistry, Sch. Science and Society, Univ. Wisconsin, Parkside Campus, Kenosha, WI 53140).

The mechanism by which extremely low frequency electromagnetic fields (ELF EMF) affect living organisms will be identified and characterized. Initially the hypothesis that the cell membrane is altered by interaction with ELF EMF will be studied. Using an organism that has been previously shown to be affected by ELF EMF, *Physarum polycephalum*, the following topics will be investigated: (a) the transport of Ca ions and glucose across the cell membrane by measuring the influx and efflux of Ca ions and the rate of glucose uptake (Experiments have been designed to isolate the membrane-dependent component of transport from the component due to intracellular processes.); (b) the electrical properties of the cell membrane by measuring changes in both membrane surface and membrane potential; and (c) electric and magnetic field components that will be applied individually and measurements (a) and (b) will be repeated. Individual field components have been observed to produce similar effects in *Physarum*; these experiments will determine whether the effects are similar at the membrane level. (funding period 1/80-12/80)

0624 AN INVESTIGATION OF THE MECHANISM OF MICROWAVE-INDUCED CHANGES IN MEMBRANE PERMEABILITY. Gartner, S. L. (Div. Medical Biochemistry, Naval Medical Res. Inst., Navy, U.S. Dept. Defense, Bethesda, MD 20014).

Supporting Agency:U.S. Dept. Health and Human Services, PHS, NIH, Natl. Inst. Environmental Health Sciences

0626 THERMAL AND NONTHERMAL EFFECTS OF MICROWAVE RADIATION. Wissler, E. H.; Diller, K. R.; Itosh, T. (Dept. Chemical Engineering, Sch. Engineering, Univ. Texas, Austin Campus, 200 W. 21st St., Austin TX 78712).

The thermal response of humans to whole-body irradiation and the changes in cellular and endothelial membrane permeability after microwave irradiation will be evaluated quantitatively in a two-part study. A comprehensive mathematical model for computing specific absorption rates and transient-state temperature profiles for irradiation under various conditions will be developed in the first part of the study. Factors that will be evaluated using this model include frequency and polarization of the incident field; subject's size, exercise, and clothing; and environmental conditions. For the second phase of the study, new and innovative experimental techniques of stopped-flow spectrophotometry, computerized microscopic densitometry, and digital velocity correlation will be applied to the analysis of transient and steady state alterations of tissue transport function. Specific studies will be conducted to characterize the biologic response to microwave irradiation according to: 1) the permeability of human erythrocytes and cultured cells to water and solutes, 2) the extravasation and interstitial diffusion of plasma macromolecules in the microvascular bed, and 3) the in vivo velocity of blood flow in the microcirculation. (funding period 4/80-3/81)

Supporting Agency:U.S. Dept. Health and Human Services, PHS, NIH, Natl. Inst. General Medical Sciences

0627 BIOELECTRIC PHENOMENA CONTROLLING BONE GROWTH. Bassett, C. A.; Pawluk, R. J.; Chokshi, H. R.; Doty, S. B.; Moran, D. (Dept. Orthopedic Surgery, Coll. Physicians and Surgeons, Columbia Univ., 630 W. 168th St., New York, NY 10032).

To investigate the mechanism of electromagnetic field effects on bone formation, the interaction between pulsing electromagnetic fields and cellular responses is being investigated, particularly as they relate to growth, cell differentiation and/or specialization, synthesis of macromolecules, and transfer of ions across the plasma membrane. Tissue culture, experimental surgery, and histochemical, biochemical, and ultrastructural analyses are being employed in a coordinated, multidisciplinary approach. Results will have not only scientific importance in defining the physiologic selectivity of electromagnetic fields with specific pulse characteristics, but will aid in increasing their therapeutic effectiveness in musculoskeletal system disorders. (funding period 2/78-1/81)

Supporting Agency:HEW, PHS, NIH, Natl. Inst. Arthritis, Metabolism, and Digestive Diseases

0628 MICROWAVE DIELECTRIC PROPERTIES OF TUMOR TISSUE. Foster, K. R.; Schwan, H. P. (Dept. Bioengineering, Sch. Engineering and Applied Sciences, Univ. Pennsylvania, 4001 Spruce St., Philadelphia, PA 19104).

The dielectric properties of various normal and tumor tissues and of cell suspensions will be measured using a coaxial line technique and microwave network analyzer. Measurements will be made in the 0.1- to 18-GHz frequency range, including the frequencies most useful for electromagnetic induction of hyperthermia. Tissues studied will include surgically excised tumors from live dogs, normal tissues from freshly killed dogs, lymphoma and ascites cell suspensions, and mouse spleen tissue. The net water content of each sample will also be measured. Dielectric data from these soft tissues will be interpreted using the Maxwell moisture theory and compared to the known properties of pure water in this frequency range to yield (a) the apparent amount of "bound" water and (b) the rotational mobility of the major fraction of water in normal and tumor tissues. This analysis will be useful for the determination of the dielectric properties of soft tissue from a single measurement of the net water content of the tissue and for the comparison of the physical properties of water in normal and tumor tissues. (funding period 7/79-6/81)

Supporting Agency:U.S. Dept. Health and Human Services, PHS, NIH, NCI

0629 MICROWAVE-INDUCED HYPERTHERMIA FOR DEEP-SEATED TUMORS. Douple, E. B.; Strohbehn, J. W.; Walsh, J. E.; Bartrum, R. J.; Roberts, D. W.; Saunders, R. L. (Dept. Medicine, Sch. Medicine, Dartmouth Coll., P.O. Box 833, Hanover, NH 03755).

An invasive irradiation system that uses microwaves in the gigahertz range to achieve local hyperthermia will be developed for the treatment of deep-seated cancers. The system will be adapted for percutaneous insertion and surgical implantation to produce appropriate hyperthermia in difficult to heat, deep-seated tumors in humans. Microwaves will be delivered directly to the tumor site through transmission lines and antenna structures. Antenna probes with diameters <1 mm will be employed. Thus, implantation can be performed with minimal disturbance to the surrounding tissue, and

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many of the problems associated with the delivery of heat to deep-seated tumors will be circumvented. The heat distributions produced by the improved system in tissue phantoms, tumors, and normal tissues of animals and humans will be predicted theoretically and measured experimentally. The therapeutic efficacy of the proposed system will be evaluated by studying the hyperthermia effects alone and in combination with ionizing radiation and chemotherapy on animal tumors and in pilot clinical studies. In addition, the effect of local hyperthermia on blood flow and the uptake of chemotherapeutic drugs in tumors and in normal tissues will be examined. Tumors will include transplantable mouse mammary adenocarcinoma (MTG-8), chemically-induced tumors in the rat, and spontaneous brain tumors in dogs. The effects of the treatment on tumor cell viability will be assessed using the TD₅₀ and tumor latency assays as well as histologic evaluation. Tumor growth, median tissue culture dose, and host life span will also be studied as indicators of therapeutic effectiveness, and normal tissue response will be carefully observed in heated animals. Clinical tumors will include brain tumors and other tumors such as pancreas and prostate cancer. (funding period 3/80-2/81).

Supporting Agency:U.S. Dept. Health and Human Services, PHS, NIH, NCI

0630 **EFFECTS OF MICROWAVE RADIATION ON THE BEHAVIORAL DEVELOPMENT OF LEARNING PROCESSES: ACUTE AND CHRONIC EXPOSURES ON ANIMALS.** Schrot, J. F.; Thomas, J. R. (Behavioral Sciences Dept., Naval Medical Res. Inst., Navy, U.S. Dept. Defense, Bethesda, MD 20014).

The effects of microwave radiation on the acquisition of behavior by rats will be studied. Initial studies will be concerned with establishing the threshold range of power densities that alter the learning process. Additional studies will focus on the long-term effects of chronic exposure. Operant conditioning techniques are used to develop a baseline of repeated acquisition of behavioral chains in rats. The schedule requires the animal to learn a different four-member response chain each session, which results in the daily generation of an individual learning curve. The baseline is used to assess the effects of low-level (near 10 mW/cm²) microwave fields. Initial emphasis is on establishing threshold radiation values producing behavioral change. Subsequent studies will focus on long-term chronic exposures with effective radiation parameters. With this methodology, microwave-produced modifications in the rate or pattern of learning may be empirically determined. (funding period 10/77-10/82)

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command, Natl. Naval Medical Center

Funding Period Modifications:

0631 **BOSE-EINSTEIN CONDENSATION IN BIOLOGICAL SYSTEMS.** Wu, T. (Dept. Physics, Sch. Arts and Sciences, State Univ. New York, Binghamton Campus, Vestal Parkway, Binghamton, NY 13901).

Funding period extended to 2/81. See Current Research 0506 for description of this project.

Supporting Agency:HEW, PHS, NIH, Natl. Inst. General Medical Sciences

0632 **INTERACTION OF ELECTROMAGNETIC FIELD WITH BIOLOGICAL SYSTEMS.** Chen, K. (Dept. Electrical Engineering and Systems Science, Sch. Engineering, Michigan State Univ., Engineering Building, East Lansing, MI 48824).

Funding period extended to 7/79. See Current Research 0267 for description of this project.

Supporting Agency:NSF, Directorate for Engineering and Applied Science

0633 **LOW LEVEL MICROWAVE RADIATION EFFECTS ON BEHAVIOR.** Thomas, J. R.; Schrot, J. E. (Behavioral Sciences Dept., Naval Medical Res. Inst., Navy, U.S. Dept. Defense, Bethesda, MD 20014).

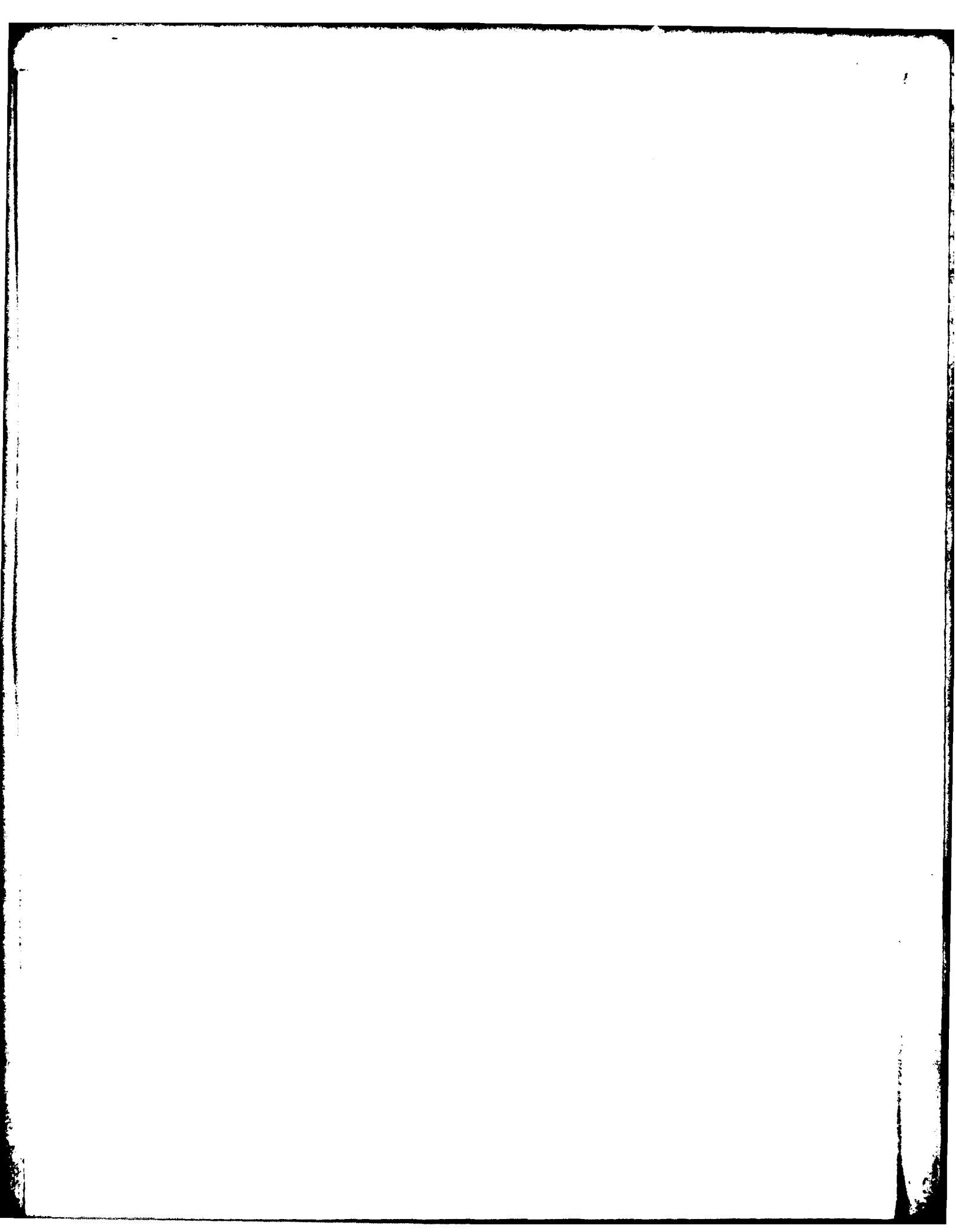
Funding period extended to 10/81. See Current Research 0492 for description of this project.

Supporting Agency:U.S. Dept. Defense: Navy, Naval Medical Res. and Development Command, Natl. Naval Medical Center

0634 REMOTE STIMULATION BY RADIO-FREQUENCY
TRANSMISSION. Glenn, W. W.; Gee, J. B.;
Allison, T.; Goff, W. R.; Lange, R. C.; Manuelliidis,
E. E.; Schachter, E. N. (Dept. Surgery, Sch. Medi-
cine, Yale Univ., 333 Cedar St., New Haven, CT 06510).

Funding period extended to 12/80. See Current Re-
search 0458 for description of this project.

Supporting Agency: HEW, PHS, NIH, Natl. Heart, Lung,
and Blood Inst.



CURRENT LITERATURE

6675 ELECTROMAGNETIC PROPERTIES OF BIOLOGICAL SOLUTIONS.-I. GENERAL CONSIDERATIONS AND PRESENTATION OF AN IMPROVED SYSTEM FOR MICROWAVE SPECTROSCOPY OF SMALL BIOLOGICAL SAMPLES. (Eng.) Bianco, B. (Laboratorio per i Circuiti Elettronici, Consiglio Nazionale delle Ricerche, 16145 Genoa, Italy); Drago, G. P.; Marchesi, M.; Martini, C.; Mela, G. S.; Ridella, S. *Boll Soc Ital Biol Sper* 55(22): 2322-2328; 1979 (25 refs).

A microwave spectroscopic method for measuring the complex permittivity of small samples of biologic liquids is described and some preliminary results are presented. The liquid under test is placed in a sample holder that acts as an infinite circular waveguide. Since the penetration depth of the electromagnetic field into the sample is very small (about 1.4 mm), a small amount of liquid (<1 ml) is sufficient to make accurate measurements. The measurement system is a Hewlett-Packard 8542A automatic network analyzer, controlled by an HP 2116C computer. Measurements made in the 100- to 2,000-MHz frequency range (in steps of 50 MHz) with liquids of known permittivity (sodium chloride solution, ethanol, and albumin) indicated that the precision of the method is normal for the real part of the complex permittivity and is good for the imaginary part of the complex permittivity.

6676 ELECTROMAGNETIC PROPERTIES OF BIOLOGICAL SOLUTIONS.-II. METHODOLOGICAL CONSIDERATIONS ON MICROWAVE SPECTROSCOPY OF HUMAN SERA. (Eng.) Bianco, B. (Laboratorio per i Circuiti Elettronici, Consiglio Nazionale delle Ricerche, 16145 Genoa, Italy); Drago, G. P.; Marchesi, M.; Martini, C.; Mela, G. S.; Ridella, S. *Boll Soc Ital Biol Sper* 55(22): 2329-2333; 1979 (1 ref).

Complex permittivity measurements were made for 20 sera of healthy young men. The measurements were made at 39 frequencies over the range of 100-2,000 MHz in 50-MHz steps. A linear regression was constructed for the serum conductivity versus the square of the frequency for all of the 39 frequencies, and the results were found to be in good agreement with theoretical predictions.

6677 ELECTROMAGNETIC PROPERTIES OF BIOLOGICAL SOLUTIONS.-III. DIFFERENCES BETWEEN SERA OF NORMAL YOUNG MEN AND CHILDREN. (Eng.) Bianco, B. (Laboratorio per i Circuiti Elettronici, Consiglio Nazionale delle Ricerche, 16145 Genoa, Italy); Drago, G. P.; Intra, E.; Marchesi, M.; Martini, C.; Mela, G. S.; Ridella, S. *Boll Soc Ital Biol Sper* 55(22): 2334-2336; 1979 (3 refs).

The electromagnetic properties of sera obtained from 20 normal adults were compared with those of

sera obtained from 15 children (1- to 6-yr old) to determine if complex permittivity is similar for healthy individuals. Complex permittivity measurements were obtained for all sera in the frequency range of 100-2,000 MHz at 50-MHz steps. Serum conductivity (SC) was obtained for all frequencies, and a regression was made versus the square of the frequency (f^2) to obtain the following relationship $SC = a + bf^2$ where a and b are assumed as characteristics of the electromagnetic properties of the sample. For all subjects, the regression $SC = a + bf^2$ showed a very high significance (lowest correlation coefficient, $r = 0.99$) and the percent standard deviation of the a and b parameters was less than 5.5%. Although the protein, albumin, and gammaglobulin contents of the sera did not differ significantly between children and adults, the parameter "a" was significantly lower in children ($p < 0.017$) than in adults. Thus, the electromagnetic properties of sera expressed by the "a" parameter seem to depend not only on serum protein content but also on some other factor related to the age of the subject. Since the "a" parameter heavily depends on the direct current conductivity of the sera, the above factor could be related to the salt percentage of the sera.

6678 THE BIOLOGICAL EFFECTS OF MICROWAVE RADIATION--A REVIEW. (Eng.) Cornelius, W. A. (Health and Safety Section, Australian Radiation Lab., Melbourne, Australia) [Report No. ARL/TR002]; 23 pp.; 1978 (58 refs).

A review of the biologic effects of microwave radiation in animals and man is presented. Most experiments conducted on the bioeffects of microwaves have employed a limited range of microwave frequencies, pulse repetition rates, and power levels, and the only interaction mechanism proven to be biologically significant is the thermal effect. Problems associated with microwave dosimetry in biologic experiments make the evaluation of the observed biologic effects difficult. Examples include nonuniform power absorption ("hot spots"), perturbation of the microwave field, and resonance conditions. The effect of microwave irradiation on animals is difficult to extrapolate from one species to another. Microwave-induced cataracts are well documented in animal experiments. For the rabbit eye the cataractogenic microwave irradiance at 2,450 MHz for a single acute 100-min exposure is about 150 mW/cm², which is equivalent to 138 W/kg peak absorption immediately behind the lens. This effect, which appears to be due to heating, occurs at an intra-ocular temperature of about 43°C for a single acute exposure. Computer modeling indicates that the temperature rise expected in the human eye would be similar to that for the rabbit for an equivalent plane wave field density. Epidemiologic studies have shown a statistically significant number of lens defects in microwave workers when compared with nonmicrowave workers, although a similar

relationship was not found for loss of visual acuity or cataract production. Eastern European countries have reported reversible effects such as headache, nausea, insomnia, tiredness, irritability, cardiac pain, loss of appetite, memory difficulties, decreased libido, changes in heart rate and blood chemistry, and alterations in electroencephalograms and electrocardiograms, and in thyroid and adrenal output at chronic exposure levels below 10 mW/cm². However, due to defects in study design, these reports have been largely discounted by western researchers. Altered behavioral responses in animals at apparently microthermal or nonthermal microwave doses appear to be due to thermal hot spots in view of the frequencies used in relation to the size of the animal. Teratogenic effects due to microwaves have also been demonstrated in animals, and these effects are evidently direct thermal effects.

6679 LONG-WAVELENGTH ANALYSIS OF NEAR-FIELD IRRADIATION OF PROLATE SPHEROIDAL MODELS OF MAN AND ANIMALS. (Eng.) Massoudi, H. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Durney, C. H.; Iskander, M. F. *Electron Lett* 16(3): 99-100; 1980 (6 refs).

A long wavelength analysis was derived for spheroidal and ellipsoidal models of man and some test animals that showed a strong dependence of electromagnetic (EM) energy absorption on orientation of the body. This analysis was applied to calculate the average specific absorption rate (SAR) in spheroids irradiated by EM near fields, when the long wavelength approximation is given, and when the spatial variation of the EM field is not "too rapid." The incident electric field and the incident magnetic fields, as well as the average SAR, were derived for an EM plane wave that was incidental on a lossy dielectric prolate spheroid along its Z-axis. The analysis gave an excellent approximation for the average SAR in a prolate spheroidal model of man as a function of dipole location.

6680 DETERMINATION OF A THERMAL EQUIVALENT OF MILLIMETER MICROWAVES IN LIVING CELLS. (Eng.) Dardalhon, M. (Institut Curie, 26, rue d'Ulm, 75005 Paris, France); Averbeck, D.; Berteaud, A. J. *J Microwave Power* 14(4): 307-312; 1979 (10 refs).

Diploid strain D5 *Saccharomyces cerevisiae* cells were irradiated at frequencies of 70.5 and 73 GHz on millipore filter discs placed on agar plates in open petri dishes to determine if microwaves can affect cell growth or induce lesions in cellular deoxyribonucleic acid (DNA). The distance between the yeast cells and frontal surface of the horn antenna was 2 or 10 mm. This yeast strain, which is sensitive

to genetic insult, was used to study the effects of both temperature (conventional heating at 30, 37, 42, 47, and 52 C) and microwave irradiation on cell survival, induction of mitotic recombination, and induction of cytoplasmic "petite" mutations. No evidence of altered survival, impaired function, or structural injury was seen at either frequency, even at power densities as high as 60 mW/cm² (duration of exposure \approx 3 hr). Conventional heating had no deleterious effects until temperatures of specimens exceeded 50 C. When two haploid strains of yeast of opposite mating type were compared with respect to temperature and microwave treatment for zygote formation, the ratio of zygotes formed in treated samples over that of control samples was observed to be a function of increasing power density and increasing temperature. The effect of conventional heating at 30 or 37 C on zygote formation was greater than the effect of 70.5-GHz microwave irradiation at a power density of 60 mW/cm². Elevation of temperature due to microwave treatment at 60 mW/cm² and 2 mm distance was estimated to be 3 C. Thus, the results of these experiments indicate that microwaves do not induce lesions and genetic effects in cellular DNA.

6681 PRELIMINARY STUDIES: FAR-FIELD MICROWAVE DOSIMETRIC MEASUREMENTS OF A FULL-SCALE MODEL OF MAN. (Eng.) Olsen, R. G. (Naval Aerospace Medical Res. Lab., Pensacola, FL 32508). *J Microwave Power* 14(4): 383-388; 1979 (10 refs).

Measurements of microwave heating were made in a 75-kg, full-size, upright human model composed of electrically simulated muscle that was placed in the far-zone of a standard gain horn inside an absorber-lined chamber. The material of the model was closely matched to human muscle in terms of permittivity and conductivity at the frequency of irradiation. Pulsed 1.29-GHz (L-band) microwaves (3- μ sec pulse duration, 310 pulses/sec repetition rate) from a military radar transmitter resulted in an average power density of 6.14 mW/cm² at the location of the model. Microwave heating at the front surface was measured at nine locations on the phantom. Measurements at several depths within the phantom were also made at a central location to assess the depth of penetration of the microwave energy. The above measurements permitted a calculation of the approximate whole-body average specific absorption rate (SAR) when the model's long axis was parallel to the electric field vector. For a normalized power density of 1 mW/cm² at a frequency of 1.29 GHz, the whole-body average SAR was 0.031 W/kg, which agrees well with the predicted value of 0.03 W/kg based on absorption in prolate spheroidal models of man.

6682 MIDDLE-EAR STRUCTURES CONTRIBUTE LITTLE TO AUDITORY PERCEP-

TION OF MICROWAVES. (Eng.) Chou, C. K. (Bioelectromagnetics Res. Lab., Dept. Rehabilitation Medicine, RJ-30, Sch. Medicine, Univ. Washington, Seattle, WA 98195); Galambos, R. *J Microwave Power* 14(4): 321-326; 1979 (9 refs).

The contribution of the ossicles (middle ear bones) and external ear bones to auditory perception of microwaves was evaluated by the brain-stem evoked response (BER) method in guinea pigs (500-750 g). The animals were placed upside down with the head inserted inside a circular microwave exposure system, and the amplitude and latency of BERs were recorded as guinea pigs were stimulated at various intensities by acoustic pulses coupled to the auditory canal or via bone conduction and by 918-MHz microwave pulses (10 μ sec pulse duration, 30 pulses/sec repetition rate). Blocking of the external ear, middle ear damping, and middle ear destruction produced little change in the BERs that were elicited by microwave pulses. The results indicated that the middle ear is not critical for auditory perception of microwaves and that the mechanisms involved in this perception are similar to those responsible for hearing by bone conduction. Also, since no response to microwave or to acoustic stimulation was recorded when the cochlea was destroyed, it is clear that microwave hearing requires activation of the cochlea. Conduction of pressure waves through the bones of the calvarium appears to be the mechanism responsible for perception of pulsed microwaves.

6683 CARBON-LOADED TEFLON ELECTRODES FOR CHRONIC EEG RECORDINGS IN MICROWAVE RESEARCH. (Eng.) Chou, C. K. (Bioelectromagnetics Res. Lab., Dept. Rehabilitation Medicine, RJ-30, Sch. Medicine, Univ. Washington, Seattle, WA 98195); Guy, A. W. *J Microwave Power* 14(4): 399-404; 1979 (15 refs).

Carbon-loaded Teflon electrodes with a conductivity close to that of tissue were implanted in cortical and subcortical locations of rabbits for periods of 4-6 mo to determine their usefulness for making chronic electroencephalogram (EEG) recordings during microwave irradiation. Two types of carbon-loaded Teflon were used. One was a fine carbon-loaded Teflon wire (0.25 by 0.3 mm cross-section) with a conductivity of 4 S/m that was used as a conductive lead and as a subcortical electrode. The other type, with a conductivity of 1 S/m, was machined into 2-56 or 4-40 screws that were used for cortical recordings. One rabbit was implanted both with conventional metal and with carbon-loaded Teflon electrodes. Three rabbits were implanted with carbon-loaded Teflon electrodes only, and two other rabbits with metal electrodes only. When a 60-Hz filter was used in conjunction with the carbon-loaded Teflon electrodes, the EEG recorded from these electrodes was indistinguishable from that recorded from metal electrodes in the absence of a microwave field. When

recordings were made during acute exposure of two rabbits to 2.450-MHz microwave radiation directed to the right eye at an incident power density of 100 mW/cm² (specific absorption rate in the hypothalamus of about 25 W/kg), there was no obvious radio frequency interference picked up by the carbon-loaded Teflon electrodes. Histologic examination showed good tissue compatibility for the carbon-loaded Teflon electrodes. The results indicate that carbon-loaded Teflon electrodes can be implanted chronically to record the EEG in animals during the course of microwave radiation.

6684 MINIATURE ANECHOIC CHAMBER FOR CHRONIC EXPOSURE OF SMALL ANIMALS TO PLANE-WAVE MICROWAVE FIELDS. (Eng.) Guy, A. W. (Bioelectromagnetics Res. Lab., Dept. Rehabilitation Medicine, RJ-30, Sch. Medicine, Univ. Washington, Seattle, WA 98195). *J Microwave Power* 14(4): 327-338; 1979 (4 refs).

A system of miniature anechoic chambers that can be used at frequencies of 2.450 MHz and higher for chronically exposing several small animals to plane-wave microwave fields is described. The system, which occupies a floor area of only 73 by 73 cm, consists of a combination of tapered and rectangular sections lined with Model AN-77 absorber material on the sides and thicker SPY-12 pyramidal absorber material on the bottom. The system allows for the simultaneous exposure of eight experimental animals, while eight sham-exposed controls are simultaneously maintained in the same environment. During actual and sham exposures, each animal is contained in a separate plastic cage that is electrically isolated from the other cages. Each animal is exposed to fields under simulated free-space conditions. Tests showed that although the plastic cage containing the animal within the exposure chamber causes field perturbation, specific absorption rate (SAR) patterns within exposed cadavers or models show very little modification. Each animal can be supplied with food and water by a system designed to eliminate severe perturbations of the field and of SAR patterns in the animals. Each chamber is mounted on casters that allow easy transport when the horn antenna assembly is removed. Experimental measurements indicated that at 1 W of input power, radiation at a power density of 169 μ W/cm² was obtained at the position normally occupied by the animal. At an incident power density of 1 mW/cm², peak SAR values as high as 0.84 W/kg were produced in a prolate spheroidal model of the rat. SARs as high as 2.21 W/kg were produced in the rat cadaver.

6685 DESIGN OF APERTURE SOURCES FOR DEEP HEATING USING ELEC-

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TROMAGNETIC ENERGY. (Eng.) Ho, H. S. (FDA, BRH, 5600 Fishers Lane, Rockville, MD 20857). *Health Phys* 37(6): 743-750; 1979 (22 refs).

Varying the source frequency, aperture size and shape, and field distribution was theoretically examined in relation to designing aperture sources that deliver deep penetration of nonionizing electromagnetic energy into different sizes of spherical tissue-equivalent bodies. Fifteen source frequencies ranging from 10 MHz to 10 GHz were used. Three types of sources were used: plane wave; "Cap" aperture, a circular aperture shaped like a polar cap in contact with the irradiated sphere; and "Belt" aperture, a loop source that wraps around the irradiated sphere. Four different sizes and three different aperture field distributions of each aperture were used. Twelve sizes of the tissue-equivalent sphere were used with radii ranging from 0.5 to 10.0 cm. For each size of the sphere, four cases were considered: a single-layered muscle sphere and three triple-layered spheres with muscle, fat, and skin layers (1.0-mm thick). The thickness of the fat layer of the three triple-layered spheres was 10, 20, and 30% of the radius of the muscle sphere, respectively. The calculated results indicated that for each source frequency, the size of the aperture source equaling $\pi/4$ yields the lowest energy penetration factor (quotient of dose rate at the sphere center by the maximum dose rate at the surface of all tissue layers of the sphere). The results indicated a strong resonance type of dependence on source frequency for deep electromagnetic energy penetration. This resonance frequency decreased with increased sphere size. The energy penetration was also a strong function of aperture size. With optimum design, the aperture sources could produce deeper energy penetration characteristics than those obtained with plane wave sources. The optimum energy penetration into smaller size spheres (<5.0 cm radius) was much greater than that for larger size spheres. In general, optimum deep energy penetration characteristics of triple-layered spheres were not as good as those of single-layered spheres.

6686 CURRENT PROBLEMS OF RADIOBIOLOGY OF RADIO FREQUENCY ELECTROMAGNETIC RADIATION. (Rus.) Akoev, I. G. (Inst. Biophysics, USSR Acad. Sciences, Pushchino, USSR). *Radicbiologiya* 20(1): 3-8; 1980 (14 refs).

Recent studies on and current problems associated with the radiobiology of radio frequency electromagnetic radiation are reviewed. Previous studies have demonstrated that most changes induced by radio frequency radiation are reversible, and morphologic changes are rare and slight. However, some irreversible changes have been observed, such as cataracts and chromosomal and genetic changes in microorganisms. Adaptation of the organism to repeated exposures of radio frequency

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radiation has been demonstrated as has a cumulation of effects from repeated exposures to ineffective small doses. Partial synergism of radio frequency radiation in the centimeter range and infrared radiation has also been observed experimentally. Little is known on the selectivity of the radiation effect on different organs. Electromagnetic radiation has been shown to have a direct or thermal effect and an indirect effect, which is manifested by such symptoms as neurosis, asthenia, and cardiovascular functional changes, especially during exposure to low-intensity radiation. The organism as a whole is assumed to be more sensitive to electromagnetic radiation than isolated organs and cells. Thus, the sensitivity is higher *in vivo* than *in vitro*.

6687 ELECTRIC CURRENT AND HIGH FREQUENCY WAVE HEATING PROCESSES. (Fre.) Dutreix, J. (Institut Gustave-Roussy, 16 bis. avenue Paul-Vaillant-Couturier, 94800 Villejuif, France); Convert, G.; Cosset, J. M.; Damia, E.; Dufour, J.; Salama, M. *J Radiol* 60(11): 669-673; 1979 (11 refs).

Recent studies on the therapeutic possibilities of capacitive, radiative, and inductive diathermy are reviewed. One study involved the use of inductive diathermy with a frequency of 27 MHz to treat skin melanoma. The depth of penetration into muscular tissue decreased with increasing frequency from 14.1 cm at 25 MHz to 1.7 cm at 3,000 MHz. A similar decrease was also observed in fatty tissue, from 154 cm at 25 MHz to 7.5 cm at 3,000 MHz. Intracavitary and interstitial diathermy is possible with the use of implanted antennas operating at such frequencies as 0.5 or 80 MHz.

6688 THERAPEUTIC APPLICATION OF CONSTANT AND LOW-FREQUENCY MAGNETIC FIELDS (LITERATURE REVIEW). (Rus.) Bogoliubov, V. M. (Central Inst. Balneology and Physiotherapy, Moscow, USSR); Skurikhina, L. A. *Vopr Kurortol Fizioter Lech Fiz Kul't* (2): 65-72, 1979 (58 refs).

Clinical and experimental reports on the therapeutic uses and effectiveness of constant and low-frequency magnetic fields are reviewed. Often combined with other conventional therapeutic methods, magnetic field therapy has been found to produce favorable results in such diseases as asthenic neurosis, arterial aneurysms, neuritis of inflammatory and ischemic etiology, lumbrosacral radiculitis, phantom pain, ischemic heart disease, hypertension, obliterating endarteritis, ulcerated varicose veins, bronchial asthma, pulmonary tuberculosis, gastric and duodenal ulcer, various gynecologic diseases (chronic adnexitis, adnexalgia,

premenstrual disorders, and chronic diseases of the uterus), fractures, psoriatic polyarthritis, and burns. Considerable palliative effect has been observed in many cases. No therapeutic effect has been observed with patients with rheumatoid arthritis. Experiments with erythrocytes have demonstrated increased storage stability due to magnetization.

6689 STATE OF THE ART AND PROSPECTS FOR THE USE OF RADIO FREQUENCY AND MICROWAVE HYPERTHERMIA. (Fre.) Gautherie, M. (Lab. Biomedical Thermology, Faculty of Medicine, French Natl. Inst. for Health and Medical Res., Université de Strasbourg, 11, rue Humann, 67085 Strasbourg cedex, France Caisse Nationale de l'Assurance Maladie des Travailleurs Salariés). *J Radioi* 60(11): 685-689; 1979 (3 refs).

Recent achievements and prospects for the use of radio frequency hyperthermia in cancer therapy are reviewed. The therapeutic use of hyperthermia is based on the fact that cell death occurs above a certain temperature (above 42°C for mammalian cells). The frequencies that have been tested to date include 13, 27, 434, and 2,450 MHz. The biologic studies on cell cultures and experimental animals should be extended to include the mechanism of action of radio frequency at the cellular level. Various technological problems are discussed, such as irradiation frequency, applicators, and dosimetry (e.g., noninterfering probes, microwave radiometry). Other topics to be considered when evaluating the prospects of microwave hyperthermia for cancer therapy include: synergism between radio frequency hyperthermia and ionizing radiation or drugs, the long-term effects of radio frequency and heat on healthy tissues, the enhancement of tumor growth and lymphogenic dissemination of tumor cells, and the specific, non-thermal effects of radio frequency radiation.

6690 MECHANISM OF ACTION AND THERAPEUTIC APPLICATION OF SINE-MODULATED CURRENTS. (Rus.) Iasnogorodskii, V. G. (Central Inst. Balneology Physiotherapy, Moscow, USSR). *Vopr Kurortol Fizioter Lech Fiz Kul't* (2): 5-13; 1979 (93 refs).

The action mechanism and possible therapeutic applications of sine-modulated currents (SMC) are reviewed. Studies have demonstrated that SMC have an analgesic effect; they have been shown to increase the blood circulation, perfusion, and trophism of tissues. SMC have also been shown to normalize the sympathetic function of the adrenals in experimental atherosclerosis and in clinical cervical osteochondrosis with neurologic symptoms. In addition, SMC treatment at 30 Hz, but not at 100 Hz, has resulted in marked changes in the nucleotide content of muscular ribonucleic acid in hypokinesia.

6691 MUSCLE BLOOD FLOW CHANGES IN RESPONSE TO 915 MHZ DIATHERMY WITH SURFACE COOLING AS MEASURED BY ^{113}Xe CLEARANCE. (Eng.) Sekins, K. M. (Dept. Mechanical Engineering, FU-10, Univ. Hosp., Sch. Medicine, Univ. Washington, Seattle, WA 98105); Dundore, D.; Emery, A. F.; Lehmann, J. F.; McGrath, P. W.; Nelp, W. B. *Arch Phys Med Rehabil* 62(3): 105-113; 1980 (20 refs).

Muscle blood flow (MBF) response of the human anterior thigh to treatment with a 915-MHz, direct-contact microwave applicator with simultaneous air-cooling ($5.0 \pm 0.5^\circ\text{C}$ at $60\text{ m}^3/\text{min}$) was measured by ^{113}Xe (0.1 ml in isotonic saline) clearance. Forty-four anterior thigh MBF studies were performed in 13 volunteers (11 men and 2 women, all 30 yr old) in 25 separate sessions. All subjects had $<1\text{ cm}$ of subcutaneous anterior thigh fat. ^{113}Xe clearance was measured at depths of either 1.5 or 3.0 cm from skin surface. Prior to treatment, resting blood flow (RBF) imaging demonstrated a uniform pretreatment perfusion field with a measured mean RBF value of 1.8 ± 1.1 and $2.06 \pm 1.03\text{ ml}/\text{min}/100\text{ g}$ at 1.5 and 3.0 cm, respectively; adjusting the RBF values for correlations with direct flow measurements found in the literature resulted in a RBF value of $2.6\text{ ml}/\text{min}/100\text{ g}$. The maximum MBF measured in response to heating with simultaneous surface cooling was $32.35\text{ ml}/\text{min}/100\text{ g}$ (mean, 27.23); this figure was in fair agreement with the reported maximum perfusion rate of $35-40\text{ ml}/\text{min}/100\text{ g}$ for skeletal muscle. To further investigate the thermoregulatory mechanisms involved with diathermy and simultaneous surface cooling, the indirect effect on the perfusion of one thigh caused by treating its counterpart was briefly studied. Results of this experiment demonstrated that 1) the effect of surface cooling a limb to depress the perfusion of its counterpart dominates that of heating one thigh to elevate blood flow in its counterpart and 2) contralateral responses to cooling diminish with depth. The results with this diathermy technique with simultaneous surface cooling demonstrate the "focusing" of perfusion and temperature into the muscle bed, thus providing therapeutic deep-heating effects while maintaining safe superficial temperatures.

6692 MICROWAVES AND HEALING OF BONE FRACTURES. (Ger.) Babayan, R. (Abteilung für Allgemeinchirurgie, Chirurgische Universitätsklinik und Poliklinik, Martinistraße 52, D-2000 Hamburg 20, W. Germany); Hahn, W.; Bensien, H. *Med Welt* 30(34): 1224-1226; 1979 (14 refs).

Osteotomy of the tibia was performed in 50 4- to 5-month-old rabbits. The fractures were set and then irradiated in 25 animals with an ERBOTHERM 12-200 apparatus (model 73, frequency $2,450 \pm 50\text{ MHz}$, 50 W, 5x for 5 min). Nonirradiated rabbits served as controls. The animals were sacrificed on day 14 or 16.

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and the tensile strength of the fractured bone was determined. Both the irradiated and nonirradiated bones refractured at the site of the primary fracture. The mean value of the tensile strength of the tibia was 6.7 kp in the controls and 7.9 kp in the irradiated animals on day 14 after osteotomy; the difference was not statistically significant. On day 16, the mean tensile strength was 7.4 kp in the controls and 9.7 kp in the irradiated animals, a statistically significant difference. These findings demonstrate that high-frequency irradiation accelerates the healing of bone fractures.

6693 FRACTURE HEALING IN RATS EXPOSED TO EXTREMELY LOW-FREQUENCY ELECTRIC FIELDS. (Eng.) Marino, A. A. (VA Hosp., Irving Ave. and Univ. Place, Syracuse, NY 13210); Cullen, J. M.; Reichmanis, M.; Becker, R. O. *Clin Orthop Relat Res* (145): 239-244, 1979 (10 refs).

The effects of full-body exposure to a 5,000 V/m electric field (1,590 V at 60 Hz) on bone healing were investigated in 27-day-old male Sprague-Dawley rats following a standardized fibular osteotomy (SFO). Both experimental and control rats (same living conditions except for the absence of the 60-Hz field) were sacrificed at 14 days postfracture. The fractures of rats exposed to 5,000 V/m electric field exhibited a distinctly altered histologic appearance compared with that of control rats. In the field-exposed rats, the new bone had much thinner trabeculae, most with cartilaginous cores, than in control rats. Large blocks of cartilage were evident throughout the callus. In some instances, a cartilage plate, exhibiting typical epiphyseal plate organization, was seen at the union site in the region of the uniting callus. New compact bone was strictly limited to the anchoring callus and was never extensively developed. After 2 wk of field exposure, fractures exhibited less new bone formation, and correspondingly more cartilage, than did control fractures. The mean healing index for the field-exposed rats was significantly less ($p < 0.001$) than that for control rats. It is concluded that bone healing in field-exposed rats was adversely affected probably because of a systemic stress interaction. The early stress response is catabolic in nature; it includes labile protein breakdown and concomitant negative nitrogen balance. Under these conditions, bone collagen synthesis may be impaired and healing time lengthened accordingly. Since this effect occurred at much lower power levels than are presently used in electrical osteogenesis, the therapeutic evaluation of electricity-promoted bone healing must consider both local and systemic effects and the local manifestations of systemic effects.

6694 THE EFFECT OF LOW FREQUENCY MAGNETIC FIELDS ON THE HEALING OF THE OSTEOTOMIZED RABBIT RADIUS. (Eng.) De

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Haas, W. G. (Orthopedic Res. Lab., Faculty Medicine, Univ. Calgary, Calgary 44, Alberta, Canada); Lazarovici, M. A.; Morrison, D. M. *Clin Orthop Relat Res* (145): 245-251, 1979 (26 refs).

The effects of noninvasive exposure to relatively strong, low-frequency magnetic fields on the healing of freshly created osteotomies of the rabbit radius were investigated using a solid core electromagnet energized by a square wave unidirectional current. The magnetic field was pulsed transversely across the osteotomy site of the radius while the animal was confined to a restraining device for 6 hr/day, 5 days/wk. In one experiment, the influence of different pulse frequencies (0.1, 1, or 4 Hz) was evaluated in 51 adult rabbits (2-4 kg), with the period of stimulation being kept constant at 2 wk; 18 nonirradiated rabbits served as controls. In a second study, pulse frequency was kept constant at 1 Hz, and the exposure period for nine animals was either 3 or 4 wk; nine nonirradiated animals served as controls. A definite healing effect was observed in comparison with nonexposed control animals when a magnetic field of 250 G, pulsed at either 0.1 or 1 Hz, was applied to the recently created osteotomy of the rabbit radius. This was especially noticeable in animals exposed to the 1-Hz pulse frequency; after 2 wk of exposure (60 hr) at this frequency, the histologic and radiologic scores in experimental animals were approximately double those of the control animals. However, the initially accelerated healing effect observed after 2 wk of magnetic field stimulation was not maintained after 3 wk. After 4 wk of exposure (120 hr), the degree of healing in experimental animals was still more advanced than in controls, but the difference in the histologic and radiologic scores was less pronounced. It appeared that although the initiation of the healing process was accelerated, the period of time required for solid union was not significantly reduced. Also, none of the osteotomies, even after 4 wk of stimulation, were judged to be completely healed on a histologic basis (i.e., bone formation in all 4 sectors). In view of these findings, this form of treatment is not recommended for clinical use in the treatment of recent fractures of long bones.

6695 AN INVASIVE MICROWAVE ANTENNA FOR LOCALLY-INDUCED HYPERTERMIA FOR CANCER THERAPY. (Eng.) Strohbehn, J. W. (Thayer Sch. Engineering, Dartmouth Coll., Hanover, NH 03755); Bowers, E. D.; Walsh, J. E.; Double, E. B. *J Microwave Power* 14(4): 339-350, 1979 (16 refs).

An invasive microwave system that uses hypodermic needle-like antennas for delivering heat directly into tumors is described. The system employs a 3- to 10-W microwave power source operating in the 500-MHz to 1.3-GHz frequency range, a coaxial transmission line, and a monopole antenna. Antennas were designed to operate at 500 MHz and 1 GHz, and

critical design parameters were identified. Absorbed power was measured in saline, in tissue equivalent phantoms, and in tumors (mouse mammary adenocarcinomas implanted in the flanks of C3H/HeJ mice) in live and dead mice. The results suggest that this system will produce significant heating in small tumors. However, the resulting thermal distributions are not sufficient for clinical applications, where a heating volume with a diameter of 2-4 cm is required. Using a 3-W, 1-GHz oscillator, temperature increases of more than 18°C were achieved in tumors of live mice in less than 10 min. Temperature profiles measured in mouse tumors indicated that this system produced significant and sufficient heating of tumor material at a 5-mm distance from the antenna. A several degree variation in tumor temperature was noted because of the large temperature rise needed to bring the anesthetized mouse from a low core temperature up to therapeutic levels of 44.5°C. It is anticipated that human tumor temperatures would be raised from 37.5 to 44-45°C and that the predicted gradient between the antenna and a distance 5 mm away would be much less. However, to have clinical relevance, antenna designs must be found that will produce flatter temperature distributions over larger volumes. Agreement between theoretical calculations and measured temperatures for the microwave antenna was quite good. The theoretical calculations predicted that there may be a small advantage in using a frequency of 3 GHz in animal tumors of about 1 cm in diameter. The microwave antenna system provides a heat distribution that is superior to that obtained using a resistance heater of similar dimensions. Future modifications of the antenna design will require measurements of absorbed power and temperature distributions *in vivo* or in very carefully constructed phantoms.

6696 PULSE-CYTOPHOTOMETRIC STUDIES ON EXPERIMENTAL BRAIN TUMORS UNDER THE EFFECT OF CHEMOTHERAPEUTIC AGENTS, MICROWAVE IRRADIATION, AND HYPERTERMIA. (Jpn.) Shitara, N. (Dept. Neurosurgery, Univ. Tokyo Hosp., Bunkyo-ku, Tokyo 113, Japan); Kohno, T.; Nagamune, A.; Takakura, K.; Sano, K. *Neruol Med Chir (Tokyo)* 18(3): 199-207; 1978 (20 refs).

To determine the best method to achieve optimal brain tumor cell synchronization as a pretreatment for radiotherapy, the results of treating cultured experimental glioma C6 strain rat tumors with various chemotherapeutic agents, hyperthermia (40°C), or microwave irradiation were analyzed. The cultured cells were exposed at the day 3 log phase stage of culture to the agents, hyperthermia, or microwaves. The microwaves, frequency 432.24 MHz (10 W), were produced using a 13.8-V direct current power supply (3.5 amp) and were maintained for 24 or 72 hr. A pulse-cytophotometer was used for a histogram analysis of the cell cycle distributions of the cultured

cells. The quantitative distribution of cell cycle phases produced by microwave irradiation after 72 hr was 42.8% (G₁ phase), 28.4% (S phase), and 28.8% (G₂ + M phase), and after 24 hr was 60.4%, 18.5%, and 21.1%, respectively. Hyperthermia for 72 and 24 hr caused cell cycle distributions in the G₁, S, or G₂ + M phase as follows: 44.1% and 46.8%, 18.7% and 32.3%, or 37.2% and 20.9%, respectively. Of the methods tested, it is suggested that the preferred pretreatment for cell synchronization for radiotherapy is the combined use of vinca alkaloids (vincristine) and nitrosourea derivatives (ACNU).

6697 ELECTROMAGNETIC HYPERTERMIA AND ITS EFFECT ON MALIGNANT TUMORS. (Cze.) Pokorny, J. (Ustave radiotechniky a elektroniky CSAV, Prague, Czechoslovakia). *Cas Lek Cesk* 118(30): 929-933; 1979 (14 refs).

Experimental results concerning the use of microwave hyperthermia to kill malignant human tumor cells are reviewed. In experiments with mice with sarcoma 180, exposure to electromagnetic radiation (frequency ranging from 0.01 to 10 GHz), at a temperature of 44.2°C for a 30-min period, resulted in irreversible damage to cancer cells (95%). Irreversible damage to cells *in vitro* was judged by the amount of DL-glyceraldehyde or oxygen accepted by the cells from the environment. At 45.2°C healthy cells were damaged. At temperatures <42°C, the effect of heat was negligible even with long-lasting exposure. The results of other studies with humans have indicated that the temperatures required to kill malignant and healthy cells are different, i.e., 45.3 and 46.2°C, respectively. Other studies have demonstrated that hyperthermia is lethal for most types of tumor cells, except for peripheral cells, which are less sensitive to heat and maintain their biologic activity, thereby propagating the tumor. Cells of various cancers differ in their sensitivity to heat, i.e., temperatures ≥44°C are lethal for human stomach cells, while temperatures ≥46°C result in death for human skin melanoma cells. The experimental results to date are inadequate to fully assess the potential usefulness of hyperthermia for treating human malignancies.

6698 ELECTROTHERAPY OF COMMON CERVICODYNIA WITH OR WITHOUT RADICULALGIA. (Fre.) Teyssandier, M. J. (Service de Rhumatologie, CHU, Nice, France). *Cinesiol* 18(72): 81-86; 1979 (7 refs).

Electrotherapy of common cervicodynia with or without radiculalgia is discussed. Electrotherapy is indicated in acute, subacute, and chronic cervicodynia, especially for cases of drug intolerance. Electrotherapy is contraindicated in infants, adolescents, and patients with pacemakers. Organs and tissues containing foreign materials, e.g.,

metals, should not be exposed. Low-frequency radiation (no dosage information specified) is indicated for analgesic purposes. Modulated and non-modulated low-frequency currents are recommended for the treatment of acute cervicodynia. Centimeter and decimeter waves have in-depth analgesic, thermal, and vasodilating effects. Meter waves are contraindicated because of their potent thermal effect. Long-pulse currents are of great value in the treatment of cervicobrachial neuralgia causing paresis.

6699 THERAPEUTIC EFFECT OF CENTIMETER PULSED WAVES IN PATIENTS WITH OSTEOARTHROSIS DEFORMANS. (Rus.) Grigor'eva, V. D. (Central Inst. Balneology Physiotherapy, Moscow, USSR). *Vopr Kurortol Fizioter Lech Fiz Kul't* (2): 36-40; 1979 (8 refs).

The therapeutic effect of pulsed wave irradiation in the centimeter range (PWI) was studied in 90 patients (59 women and 31 men, aged <40 to >60 yr) with osteoarthritis deformans. Stage I was diagnosed in 19 patients, stage II in 58, and stage III in 13. The length of the disease was 1-25 yr. The pulse frequency was 70 or 700 Hz, the power output was 0.8 W, and the duration of the treatment was 5-7 min/day or every other day for 12-18 sessions. A favorable effect of the treatment (alleviation of arthralgia, disappearance of exudation in secondary synovitis, and improvement of the function of the joints) was observed after the first 4-6 sessions. Improvement continued until the end of treatment. Alleviation of leukocytosis, reduction of blood hexose level in the patients with secondary synovitis, and normalization of the glycoprotein and lipid levels were also observed. Blood pressure, which had been increased, normalized during treatment. There was no epicardial pain, nor were there any significant electrocardiogram changes. The results demonstrated that the treatment had a general analgesic and antiinflammatory effect. The therapeutic effect was greatest at 70 Hz and it was comparable to that observed in control patients treated with a permanent magnetic field (20-40 W).

6700 LOW-FREQUENCY VARIABLE MAGNETIC FIELD FOR THE TREATMENT OF PATIENTS WITH RHEUMATOID ARTHRITIS OF THE KNEE JOINTS. (Rus.) Silin, L. L. (Dept. Traumatology, Orthopedics, and Military Field Surgery, I. M. Sechenov First Moscow Medical Inst., Moscow, USSR); Brovkin, S. V.; Gorfinkel', I. L.; Vinogradov, E. V. *Vopr Kurortol Fizioter Lech Fiz Kul't* (2): 41-43; 1979 (3 refs).

Sixty-four patients (45 men and 19 women, aged 35-83 yr) with rheumatoid arthritis of the knee joints underwent magnetotherapy with a low-frequency magnetic field (50 Hz, 200 Oe, 10-15 min/day in 10-day cycles,

repeated at 5-day intervals for up to 30 sessions). The duration of the disease was 5-23 yr. Primary and secondary rheumatoid arthritis were diagnosed in 29 and 35 cases, respectively. Twenty-one patients were in stage II and 43 were in stage III. Thirty-three patients in stages II and III without pronounced secondary synovitis received magnetotherapy only (group 1); the other 31 patients (group 2) in stages II and III with pronounced secondary synovitis received intra-articular hydrocortisone injections (25 mg) before sessions 1 and 8; their magnetotherapy consisted of 15-20 sessions. The control group consisted of 40 patients with pronounced secondary synovitis who were treated with hydrocortisone only. Inflammation and nocturnal pain disappeared during or immediately after the magnetotherapy in most patients in group 1. The nocturnal pain and inflammation disappeared in 25 patients in group 2; 4 patients achieved considerable improvement. The therapeutic effects were similar in the two groups, but they appeared sooner in group 2 than in group 1. The total necessary hydrocortisone dose was smaller in group 2 than in the controls. Forty-eight patients were followed up for 6-24 mo; positive therapeutic effects continued in 24 cases; 19 patients had periodic exacerbations; and 5 cases showed no improvement.

6701 ELECTROSTIMULATION WITH SINE MODULATED CURRENTS IN THE COMPLEX TREATMENT OF PATIENTS WITH DISEASES OF THE SPINAL CORD ASSOCIATED WITH SPASTIC AND MIXED PARESES. (Rus.) Bagel', G. E. (Dept. Physiotherapy, Belorussian Postgraduate Medical Inst., Minsk, USSR). *Vopr Kurortol Fizioter Lech Fiz Kul't* (2): 32-36; 1979 (9 refs).

Electrostimulation with modulated sine currents was performed in the complex treatment of 50 patients (35 men and 15 women) with spastic paraplegia (5 cases), spastic paraparesis (27), or mixed paraparesis (18). The duration of the disease was up to 3 mo in 13 cases, up to 6 mo in 10, up to 6-12 mo in 10, and >12 mo in 17. Pronounced spasticity was observed in 14 cases, moderate spasticity was observed in 25, and mild spasticity was observed in 11. The antagonists of the spastic muscles were stimulated in the patients with spastic paraparesis and the peroneal nerves and long peroneal muscles were additionally stimulated in the patients with mixed paresis. Contact electrodes were placed in the electromotor points and the muscle-tendon junctions. The modulating frequency was 150 Hz for cases of pronounced spasticity and 30-100 Hz for cases of mild and moderate spasticity and mixed paresis. The modulation factor was 50-75%, the current intensity was 30-40 mA, and the duration of the pulse plus pause was 2-3 sec. The treatment consisted of 20-40 courses, each of 2- to 3-min duration. After treatment, 8 patients achieved considerable improvement, 33 achieved moderate improvement, and 9 patients achieved slight improvement. The therapeutic

effect was best when the electrostimulation was administered within 1-12 mo; good results were also obtained, however, when the patients were treated during the later phase of the recovery period (1-3 yr). Early treatment (1-3 mo from the onset of the disease) prevented the aggravation of spasticity.

6702 COMPLEX CONSERVATIVE THERAPY OF ACUTE PANCREATITIS WITH THE USE OF PERMANENT MAGNETIC FIELDS. (Rus.) Val'ter, E. O. (Dept Clinical Surgery, Izhevsk Medical Inst., Izhevsk, USSR). *Sov Med* (2): 34-38; 1980 (13 refs).

Experience with the use of permanent electromagnetic fields for the treatment of acute pancreatitis in 25 dogs and 109 patients (22 men and 87 women) is reported. Pancreatitis was induced in 25 dogs by introducing bile into the pancreatic tissue. Twenty dogs were treated with an electromagnetic field by applying two radiation sources (magnetophores, 360 Oe each) for 10-20 days; 5 untreated dogs served as controls. The mortality was 6/20 in the experimental group and 5/5 in the control group. Compared with the controls, the experimental animals showed a more rapid normalization of the trypsin, trypsin inhibitor, and amylase levels. In the clinical trials, 80 patients with acute pancreatitis and 29 with cholecystopancreatitis received electromagnetic treatment by wearing two magnetophores (360 Oe each, gradient 41 Oe/mm) continuously for a few hours or up to 2-3 wk, depending on the seriousness of the clinical picture and the therapeutic effect in connection with the standard conservative treatment. The magnetophores were placed on the anatomic projections of the pancreas on the abdomen and back. The urine diastase level returned to normal in 4-5 days and the blood amylase and trypsin levels normalized in 6-10 days, but the trypsin inhibitor level remained elevated for 20 days. Improvement was seen in 14 patients within the first 5 days of complex treatment, on day 10 in 17, on days 14-15 in 17, on days 15-20 in 35, and after 20 days in 2. The therapeutic results were more favorable than those reported for an untreated control group (results not available). These findings suggest that the magnetic field acts not only on the trophic connections between the active sites of the skin and the internal organs, but also directly on the pancreas, thus potentiating the effects of drugs.

6703 VERY LOW FREQUENCY AND SMALL INTENSITY ELECTROMAGNETIC AND MAGNETIC FIELDS AS AN OECOLOGICAL FACTOR. (Eng.) Achkasova, Iu. N. (Crimean Medical Inst., bul. Lenina 5/7, Simferopol, USSR); Pyatkin, K. D.; Bryzgunova, N. I.; Sarachan, T. A.; Tyshevich, L. V. *J Hyg Epidemiol Microbiol Immunol (Praha)* 22(4): 415-420; 1978 (13 refs).

The effects of very low frequency and intensity elec-

tromagnetic fields (EMF) and magnetic fields (MF) on the biologic properties of several strains of bacteria (*Staphylococcus aureus*, *Bacillus anthracoides*, *Klebsiella pneumoniae*, *Escherichia coli*, *Salmonella typhimurium*, and *Shigella sonnei*) were examined. The bacteria were exposed to EMF and MF either for 4 hr/day or repeatedly for 8 hr/day (20-30 passages). EMFs of 0.1 Hz and 0.4 V/m, 0.5 Hz and 0.4 V/m, 1.0 Hz and 0.4 V/m, and 1-20 kHz and 4 mV/m stimulated the rate of cellular proliferation, increased bacterial enzyme activity, produced no change in the type of nutrition, and increased resistance to antibiotics. An EMF of 0.5 Hz and 100 V/m inhibited the rate of proliferation and enzyme activity, produced unstable auxotrophs, and increased resistance to antibiotics. An MF of 0.1 Hz and 0.5 gamma inhibited the rate of proliferation, resulted in maltose-negative enzyme activity, produced auxotrophs, and increased resistance to antibiotics. MFs of 0.6 Hz and 1 gamma, 0.5 Hz and 16 gamma, 0.5 Hz and 30 gamma, 0.5 Hz and 46 gamma, and 0.5 Hz and 92 gamma inhibited the rate of proliferation and enzyme activity and produced auxotrophs. MFs of 0.6 Hz and 1 gamma, 0.5 Hz and 46 gamma, and 0.5 Hz and 92 gamma increased resistance to antibiotics, while MFs of 0.5 Hz and 16 gamma and 0.5 Hz and 30 gamma decreased resistance to antibiotics. A single exposure to both EMF and MF changed the rate of bacterial proliferation; however, the rate returned to normal when the exposure was discontinued. Resistance to antibiotics and the development of auxotrophs were observed after long-term exposure. Considerable scatter of results was observed in all experiments. A study of the fluctuations of natural MFs during the experimental period revealed that the growth of bacteria in a control group was greatly influenced by magnetic storms. Thus, it is necessary to take into consideration perturbations of the geomagnetic field when studying the effects of very low frequency and intensity MFs and EMFs on bacteria.

6704 EXPERIMENTAL EFFECTS OF COMBINED EXPOSURE TO INFRASOUND AND ULTRA-HIGH FREQUENCY ELECTROMAGNETIC FIELDS. (Rus.) Gabovich, R. D. (Kiev Medical Inst., Kiev, USSR); Shutenko, O. I.; Koziarin, I. P.; Shvaiko, I. I. *Gig Sanit* (10): 12-14; 1979 (6 refs).

The physiologic effects of exposure to infrasonic waves (8 Hz, 110 dB, 2 hr/day for 10 consecutive wk), an ultra-high frequency electromagnetic field ($100 \mu\text{W/cm}^2$, 2.375 + MHz, 2 hr/day for 10 consecutive wk), and their simultaneous application were studied in 160 male albino rats (initial body wt. 130 + 5 g). The animals were divided into four equal groups: group 1 received no treatment, group 2 received electromagnetic radiation, group 3 received infrasonic waves, and group 4 received both infrasonic waves and electromagnetic radiation. The animals were examined before and 2, 6, and 10 wk after exposure. Slight retardation in weight gain (by 11-13%) was

observed in all groups 2 wk after exposure, but it was significant in group 4 only ($p < 0.05$). Performance capacity (as measured by a swimming test) was significantly reduced ($p < 0.05$) only in group 4 by the end of the experiment. The summation threshold index, reduced in group after 2 wk, was significantly increased after 6 wk in groups 3 (16.9 ± 0.69) and 4 (18.1 ± 0.65) compared to the controls (14.5 ± 0.36). The latent period for unconditioned reflexes was reduced in group 4 compared with controls after the first 2 wk; it was significantly increased in all three exposed groups at 6 wk, but it remained significantly increased until the end of the experiment in group 4 only (60.2 ± 2.5 msec). The duration of hexobarbital-induced sleep was significantly prolonged in all three exposed groups after the second experimental week, but it remained increased until the end of the experiment in group 4 only. Blood cholinesterase activity was significantly reduced in the three exposed groups at 2 wk, but no difference was observed at the end of the experiment. Oxygen consumption was reduced in group 2 only (by 7.7%) at the end of the experiment. After an initial stimulation, the thyroid function was depressed in the exposed groups at the termination of the experiment: radioiodine uptake was 33% in group 2, 28.7% in group 3, and 25.4% in group 4 versus 36.9% in the controls. These findings demonstrate a synergistic effect for the combined exposure to infrasonic waves and ultra-high frequency electromagnetic waves.

6705 NEW STEP IN THE HYGIENIC SUPERVISION OF THE USE OF ELECTROMAGNETIC RADIATION SOURCES IN MOSCOW. (Rus.) Appenianskii, A. I. (Public Health Epidemiology Station, Moscow, USSR); Gordon, Z. V.; Tsessarskii, A. V. *Gig Tr Prof Zabol* (10): 49-51; 1979 (7 refs).

Reports describing the hygienic inspection of work places and workers exposed to electromagnetic radiation in Moscow are reviewed. Three hundred thousand measurements of radiation levels were performed during the period 1968-1978. The maximum allowable radiation levels (not specified) were exceeded in 29-37% of all cases. Exposure to electromagnetic fields was reported to impair the resistance of exposed workers to other harmful environmental factors (e.g., infections) and to increase the incidence of some diseases, such as ischemic heart disease. The hygienic inspection will be extended to all frequencies of nonionizing radiation and radiation levels will also be measured in the general urban environment outside of industrial work places. In addition, the health status of workers exposed to electromagnetic radiation and other adverse factors will be monitored. New equipment including electromagnetic radiation sources will be subjected to

hygienic evaluation at the design stage and during testing.

6706 NEW VDE REGULATIONS FOR MICROWAVE OVENS. (Ger.) Schroth, H. (No affiliation given). *Electrotech Z* 100(20): 1100-1102; 1979 (4 refs).

New Association of German Electrical Engineers (VDE) regulations for microwave ovens are presented. Warning labels are required on the microwave ovens only if the radiation intensity exceeds 5 mW/cm^2 when one of the covers is removed (e.g., for repair). The leakage radiation intensity must not exceed 5 mW/cm^2 during attempts to open the door with all but the principal safety interlocks out of order. The maximum permissible leakage for both intact and repaired microwave ovens is 5 mW/cm^2 .

6707 A REVIEW OF SELECTED BIOLOGICAL EFFECTS AND DOSIMETRIC DATA USEFUL FOR DEVELOPMENT OF RADIOFREQUENCY SAFETY STANDARDS FOR HUMAN EXPOSURE. (Eng.) Tell, R. A. (Office Radiation Programs, EPA, P.O. Box 18416, Las Vegas, NV 89114); Harlen, F. J. *Microwave Power* 14(4): 405-424; 1979 (88 refs).

Bases for developing radio frequency (RF) exposure standards, which can be related to the thermogenic properties of electromagnetic fields, are presented. In addition, selected biologic effects, including dosimetric data, that are pertinent to the development of the standards are reviewed. On the basis of available bioeffects data, the following conclusions seem reasonably supportable. When an animal is thermally loaded to approximately its basal metabolic rate (BMR) value, noticeable signs of heat stress become evident. Clearly discernible elevations of rectal temperature in laboratory animals can occur at thermal loads as low as 20-30% of the BMR. Although numerous behavioral and endocrine effects as well as heart and respiration rate changes are observed at specific absorption rates below the equivalent of an animal's BMR, there is little evidence that these observed effects are anything but manifestations of normal physiologic responses to mild thermal stress. When RF induced thermal loads exceed about twice the BMR in small laboratory animals, the thermal stress, when maintained on a continuous and protracted basis, leads to significant shifts in various physiologic indices that indicate unacceptable chronic strain if maintained for indefinitely long periods of time. There are no data that indicate that

pulsed electromagnetic fields are any more hazardous than an equivalent average power continuous wave field. Based on the analogy of thermal-stress standards that have been developed for hot industrial environments, limits on increases of body temperature are proposed as criteria for limiting exposure to RF fields, i.e., occupational exposures involving deep heating of the whole body should not increase core temperature in excess of 1°C. However, since energy deposition from exposure to some RF fields is likely to be nonuniform and may be high in tissues that are not adapted to high rates of absorption or dissipation of thermalizing energy, means are needed to adjust focal thermal loading against the whole-body averages. A limit on core temperature is inadequate when focal elevations of temperature are close to the limits for protein denaturation; this may occur even though the core temperature may rise less than 1°C. On the basis of available data, it is concluded that the safe value for continuous exposure to 10 mW/cm² appears to provide an adequate margin of safety for both occupational and environmental exposure for frequencies above about 1 GHz. This limit may be too high (perhaps by an order of magnitude) for some frequencies below 1 GHz where body resonances cause a significant increase in energy deposition and where local temperature rises occur. It is also concluded that the present averaging period of 0.1 hr seems unjustifiably short.

6708 RISKS OF MICROWAVES AND RADIO WAVES FOR HUMANS. (Ger.) Bernhardt, J. (Institut für Radiologie, Universität Erlangen, Krankenhausstrasse 12, 8520 Erlangen, W. Germany). *Dtsch Med Wochenschr* 104(50): 1757-1761; 1979 (32 refs).

Studies of the effects of microwaves and radio waves on the human body are reviewed. On a molecular level, the electromagnetic field causes the motion and partial rotation of polar molecules, which leads to the development of heat due to frictional losses. Thermal denaturation of macromolecules occurs only in fields of extremely high intensity. Nonthermal effect (excitation of nerve and muscle cells) may occur at frequencies below 30 kHz and at sufficiently high field intensity. Microwaves and radio waves with frequencies above 30 MHz generate heat in exposed tissues. The penetration of such waves is 0.1-100 mm. At power densities >100 mW/cm², the eye is the critical organ, and irradiation may cause cataracts. The recommended maximum permissible power density for exposure exceeding 0.1 hr is 10 mW/cm² or 200 V/m and 0.5 A/m. Whole-body effects may be manifested above 30-100 mW/cm². The recommended maximum power density for whole-body exposure for less than 0.1 hr is 1 mW/cm². Radio waves as well as electrical and magnetic fields below 30 MHz generate heat and excite nerve and muscle cells.

Their penetration depth may exceed 100 mm. In the frequency range of 3-30 MHz, the recommended maximum permissible field parameters are 1.5 kV/m and 4 A/m for long-term exposure exceeding 0.1 hr. In the range of 10 kHz-3 MHz, the recommended maximum permissible field parameters are 3 kV/m and 8 A/m for long-term exposure (>0.1 hr).

6709 ACUTE MICROWAVE IRRADIATION: REPORT OF A CASE TREATED RECENTLY AT BEGIN HOSPITAL. (Fre.) Delahaye, R. P. (Clinique de Rheumatologie, Hopital Begin, Saint Mandé, France); Doury, P.; Conrad, J.; Metges, P. J.; Pattin, S. *Med Aeronaut Spat* 18(72): 293-296; 1979 (4 refs).

A 36-yr-old technician was exposed to whole-body microwaves for about 20 min while repairing radar equipment. The power density was estimated to be 10 mW/cm²; the wavelength was 1.3 cm; the pulse length was 0.5 μ sec; and the pulse frequency was 4,000 Hz. The exposure produced a sensation of heat, especially in the hands, and dorsolumbar pains, which prompted the technician to leave the exposed area. The patient was unable to move for several hours. Primary treatment consisted of bed rest and treatment with analgesics. The patient was in good condition 3 days after the exposure, but nausea without emesis persisted for a few weeks. Thorough, comprehensive clinical examinations, performed a few weeks after exposure, failed to reveal any abnormal changes. The ophthalmologic and neurologic findings were normal.

6710 TIME PARAMETERS IN MICROWAVE IRRADIATION (ABSTRACT). (Eng.) Davydov, B. I. (No affiliation given); Antipov, V. V.; Tikhonchuk, V. S. *Eng Mon Index* 18(1): 418; 1980 (19 refs).

The time characteristics of injury and recovery after microwave irradiation were analyzed from experiments on 3,080 mice and 604 rats. The processes resulting from exposure to microwave and ionizing radiation were subjected to a formal comparative analysis. The analysis indicated a similarity between the effects of exposure to microwave and ionizing radiation.

6711 EFFECTS OF CENTIMETER-WAVE IRRADIATION AND INDUCTOTHERMY ON

CURRENT LITERATURE

Biological Effects of Nonionizing Electromagnetic Radiation V(1), September 1980

THE ADRENAL CORTEX FUNCTION IN CHILDREN WITH BRONCHIAL ASTHMA. (Rus.) Stepanova, L. T. (Moscow Inst. Pediatrics and Pediatric Surgery, Russian SFSR Ministry Public Health, Moscow, USSR); Gromova, V. N.; Titov, G. N.; Terfilova, E. V.; Iudaeva, N. I.; Strekalovskaya, N. N. *Vopr Kurortol Fizioter Lech Fiz Kul't* (2): 26-31; 1979 (10 refs).

The effects of centimeter waves and of inductothermy on the function of the adrenal cortex was studied in 150 children aged 5-15 yr with bronchial asthma of allergic-infectious etiology (70% of the children) or of allergic etiology only (30%). Severe asthma was diagnosed in 20 patients and moderate asthma was diagnosed in 130. Group 1 consisted of 79 children subjected to centimeter wave irradiation (frequency not given; 2 W for those in the 5-7 yr bracket, 4 W for those in the 7-10 yr bracket, and 6-8 W for those in the 11-15 yr bracket) for 10 min every day or every other day, totaling 8-10 courses. Group 2 included 36 children aged 5-8 yr who received contact inductothermy (UHF, output 30 W) for 10 min every day or every other day, totaling 10-12 courses. Thirty-five children served as controls. In addition, the children also received a regulated diet, vitamins, hormones (13 cases), and specific desensitization (19 cases). In children with moderate asthma in group 1, the serum cortisol and corticosterone levels were 10.1 $\mu\text{g}\%$ and 9.8 $\mu\text{g}\%$, respectively, before treatment and 12.9 $\mu\text{g}\%$ ($p<0.002$) and 6.9 $\mu\text{g}\%$ ($p<0.001$), respectively, after treatment. In group 2, the levels were 8.8 $\mu\text{g}\%$ and 11 $\mu\text{g}\%$, respectively, before treatment and 9.9 $\mu\text{g}\%$ and 8.9 $\mu\text{g}\%$ ($p<0.05$), respectively, after treatment. The respective serum levels for controls were 9.8 $\mu\text{g}\%$ and 8.7 $\mu\text{g}\%$ before treatment and 8.7 $\mu\text{g}\%$ and 8.2 $\mu\text{g}\%$ after treatment. The C21 corticosteroid level and the 17-oxy corticosteroid/17-deoxycorticosteroid ratio increased significantly after treatment in group 1. Along with the activation of corticosteroid biosynthesis, the hepatic metabolism of these hormones was also increased. Similar changes were seen in group 2. In the children with the most severe form of asthma, who had been on long-term hormone treatment, treatment with centimeter waves and inductothermy was ineffective; the treatment caused a further deterioration of the adrenal cortex function. The therapeutic effect was better in children aged 5-8 yr in group 1 than in group 2. The findings indicate that centimeter wave irradiation and inductothermy have a pronounced clinical effect, i.e., normalization of the adrenal cortex function in children with moderate cases of bronchial asthma. This treatment is not indicated for patients with severe bronchial asthma.

6712 MECHANISM OF THE BIOLOGIC EFFECT OF INDUSTRIAL FREQUENCY ELECTROMAGNETIC FIELDS. (Rus.) Levchuk, Iu. N. (No affiliation given.); Dyshlovoi, V. D.; Kachura, V. S.; Vybornyi, V. P. *Elektron Obrab Mater* (6): 64-71; 1979 (9 refs).

The general principles and the physical aspects of the biologic effect of industrial frequency (50 Hz) electromagnetic fields are described. In addition, the results of in vitro experiments of the effects of electromagnetic fields (50 and 150 kV/m) on human peripheral lymphocytes and embryonal fibroblast-like cells are presented. Exposure to the electromagnetic field caused disturbances in the growth and development of the cultures: ultrastructural changes in the chromatin in the nuclei, nucleoli, and cytoplasmic organelles; and a reduction in mitotic activity. The passage of the cells in the phase of deoxyribonucleic acid synthesis within the mitotic cycle was slowed, the duration of the S phase was prolonged, and ribonucleic acid and protein syntheses were inhibited. These experimental data give indirect evidence of the direct effect of industrial frequency electromagnetic fields on cells.

6713 CHANGES IN THE BIOLOGIC ACTIVITY OF CERTAIN RABBIT BRAIN STRUCTURES UNDER THE EFFECT OF MICROWAVES. (Rus.) Ershova, L. K. (Inst. General Municipal Hygiene, Kiev, USSR); Rudnev, M. I. *Fiziol Zh* 25(2): 132-138; 1979 (18 refs).

The effects of microwave irradiation (2.375 ± 50 Hz; energy flux density of 1, 5, 10, 50, and 500 $\mu\text{W}/\text{cm}^2$; length of exposure, 7 hr/day for 3 mo) on the bioelectric activity of various brain structures (posterior hypothalamic nucleus, central median thalamic nucleus, and sensory-motor and visual cortices) were studied in 36 male chinchilla rabbits (body wt 2.7-3.5 kg). The animals were irradiated by the distance method in anechoic chambers. Exposure to 1 and 5 $\mu\text{W}/\text{cm}^2$ caused insignificant changes in the biopotentials, while exposure to 10-500 $\mu\text{W}/\text{cm}^2$ caused considerable changes in the bioelectric activity of the cortical and subcortical structures. Two weeks of exposure to 10 $\mu\text{W}/\text{cm}^2$ microwaves caused a 19.7% increase in the alpha-rhythm index of the sensory-motor cortex and a 43.2% increase for the visual cortex. The amplitude also increased--by 53.4% in the sensory-motor cortex and by 75.8% in the visual cortex. These changes appeared slightly later in the subcortical structures. The bioelectric processes were inhibited by 500 $\mu\text{W}/\text{cm}^2$ during the initial period. The findings indicate that microwave irradiation with $>10 \mu\text{W}/\text{cm}^2$ causes an increased excitability and lability of the nerve centers of certain cortical brain structures; these changes are less marked in the subcortical structures due to the limited penetration of the radiation.

6714 CALCIUM AND MAGNESIUM LEVELS IN RAT TISSUES UNDER THE EFFECTS OF INDUSTRIAL-FREQUENCY ELECTROMAGNETIC FIELDS. (Rus.) Dyshlovoi, V. D. (A. A. Bogomolets Medical Inst., Kiev, USSR); Radlovskaia, Z. T.; Arkhipchuk, V. D.; Kachura, V. S. *Gig Tr Prof Zabol* (2): 46-47, 1980 (no refs).

The effect of exposure to an electromagnetic field (50 kV/m, 50 Hz, for 5 hr) on the calcium and magnesium levels in the liver, thymus, kidneys, brain, hip muscles, tongue, testicles, prostate, heart, lungs, stomach, spleen, large and small intestines, and adrenals was studied in seven male Wistar rats (body wt 180-220 g). Seven untreated animals served as controls. The animals were decapitated immediately after exposure. The calcium levels were significantly reduced in the liver (1.781 versus a control value of 3.534 $\mu\text{g/g}$ dry tissue wt, $p<0.001$) and thymus (2.863 versus 5.202 $\mu\text{g/g}$, $p<0.01$), and were significantly increased in the kidneys (3.016 versus 1.376 $\mu\text{g/g}$, $p<0.05$), brain (3.347 versus 1.367 $\mu\text{g/g}$, $p<0.001$), hip muscles (2.905 versus 693 $\mu\text{g/g}$, $p<0.001$), tongue (2.831 versus 916 $\mu\text{g/g}$, $p<0.01$), testicles (4.945 versus 1.526 $\mu\text{g/g}$, $p<0.01$), and prostate (2.157 versus 1.053 $\mu\text{g/g}$, $p<0.001$). The magnesium levels were significantly reduced in the liver (1.223 versus 1.565 $\mu\text{g/g}$, $p<0.001$) and thymus (1.484 versus 2.381 $\mu\text{g/g}$, $p<0.01$), and were significantly increased in the brain (1.362 versus 901 $\mu\text{g/g}$, $p<0.001$), hip muscles (1.731 versus 1.321 $\mu\text{g/g}$, $p<0.05$), tongue (1.266 versus 818 $\mu\text{g/g}$, $p<0.01$), testicles (2.042 versus 1.426 $\mu\text{g/g}$, $p<0.05$), and prostate (974 versus 721 $\mu\text{g/g}$, $p<0.01$).

6715 SIGNIFICANCE OF BLOOD LIPID AND ELECTROLYTE DISTURBANCES IN THE DEVELOPMENT OF SOME REACTIONS TO MICROWAVES. (Rus.) Sadchikova, M. N. (Inst. Industrial Hygiene Occupational Diseases, USSR Acad. Medical Sciences, Moscow, USSR); Khariamova, S. F.; Shatskaiia, N. N.; Kuznetsova, N. V. *Gig Tr Prof Zabol* (2): 38-39, 1980 (6 refs).

Physiologic and biochemical changes were studied in 50 men (aged 32-50 yr, average age 42 yr) who were occupationally exposed to low-intensity microwave radiation for several years (5-15 yr, average 13 yr). The field intensity reached several hundred $\mu\text{W/cm}^2$ and the daily exposure did not exceed 2-3 hr. Seventy-nine men, not exposed to electromagnetic fields, served as controls. Dermatographia, hyperhidrosis, labile pulse and a tendency for hypertension, cardialgia, and changes in conduction were seen in the exposed group (no corresponding data available for controls). Compared with the controls, there were significant decreases in the blood chloride level and in the intracellular sodium level;

the blood chloride level ranged from 274 to 380 mg° in 67.6% of the exposed workers (compared with 393 mg° as the lower limit of the normal range) and the intracellular sodium level was 31.9 mg° (average value). Compared with the controls, the serum triglyceride, β -lipoprotein, cholesterol, and phospholipid levels were increased significantly in the exposed workers. The changes were most marked in the triglyceride and β -lipoprotein levels, the triglyceride level ranged from 157 to 259 mg° in 63.6% of the cases (compared with 151 mg° as the upper limit of the normal range) and the β -lipoprotein level ranged from 783 to 1,659 mg° in 50.2% of the exposed workers. These findings indicate that long-term exposure to low-intensity electromagnetic fields causes changes in the blood electrolytes and serum lipids.

6716 EFFECT OF ELECTROMAGNETIC RADIATION AT 2.45 GHz FREQUENCY ON DBA2 MICE: EFFECT ON SERUM TRIGLYCERIDES AND β -LIPOPROTEINS. (Fre.) Laurens, S. (Departement d'Etudes et de Recherches en Microondes, Centre d'Etudes et de Recherches de Toulouse, Toulouse, France); Dumas, J. C.; Roux, G. *Arch Sci* 32(2): 181-187, 1979 (14 refs).

The effect of exposure to electromagnetic fields of different intensities at a fixed frequency (2.45 GHz) for 63 hr on the serum triglycerides and β -lipoproteins was studied in purebred DBA2 mice. The field intensity was 1.2 mW/cm^2 in group A (72 animals), 3 mW/cm^2 in group B (36 animals), 5 mW/cm^2 in group C (72 animals), 8.4 mW/cm^2 in group D (48 animals), 10.2 mW/cm^2 in group E (48 animals), 12 mW/cm^2 in group F (84 animals), and 15 mW/cm^2 in group G (48 animals). Nonirradiated animals served as the controls. Irradiation caused a nonlinear increase in the serum triglyceride levels. The increase was observed as follows: A, B > C, D, E > G > F; the level was increased by 46% in group F. The β -lipoprotein level showed a nearly linear increase with increasing field intensity, exceeding 40% at 15 mW/cm^2 . There were no significant changes in the cholesterol level. The changes in the triglyceride and β -lipoprotein levels produced observable results at intensities greater than 3 mW/cm^2 .

6717 DYNAMICS OF THE IMPULSE ACTIVITY OF NEURONS OF THE POSTERIOR LOBE OF THE HYPOTHALAMUS UNDER THE EFFECT OF MICROWAVES. (Rus.) Faitel'berg-Blank, V. R. (Dept. Pathophysiology Biophysics, Odessa Agricultural Inst., Odessa, USSR). *Fiziol Zh* 25(2): 199-202, 1979 (8 refs).

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The effect of an electromagnetic field (wavelength 12.6 cm, field intensity 0.5 or 5 mW/cm², length of exposure 10 min) on the impulse activity of 128 nerve cells of the mamillary bodies of the hypothalamus was studied in 18 male chinchilla rabbits (body wt 2-3 kg). The vibrator was oriented parallel to the body axis at a distance corresponding to 4 wavelengths from the head of the animal. Depending on the type of background activity, 68% of the cells generated irregular solitary action potentials (type 1), 11% generated action potentials clustered in discharges (type 2), and 21% generated solitary and clustered action potentials (type 3). An electromagnetic field of 0.5 mW/cm² caused an increase in the discharge frequency of the nerve cells. The highest percent (80%) of excited neurons was recorded during 4 min of exposure. Before exposure, the discharge frequency of the majority of the cells was 1-7 impulses/sec, increasing to 8-14 impulses/sec during irradiation. The highest percent (22%) of inhibited cells occurred during 10 min of exposure. The impulse activity of the cells returned to the background level 4 min after exposure. Under the effect of 5 mW/cm², there was a considerable decrease in the percent of cells responding with increased peak frequency. The percent of excited neurons was highest (62%) during 3 min of exposure, and the percent of inhibited cells was highest (36%) during 5 and 10 min of exposure. The impulse activity returned to normal levels 4-5 min after exposure. Four percent of the cells showed increased frequency of the action potentials, while a decrease was seen in 5% in the nonexposed controls.

6718 EFFECT OF UHF ELECTRICAL FIELDS ON SPERMATOGENESIS. (Rus.) Danilova, I. N. (Central Inst. Dermatology Venereal Diseases, Central Inst. Balneology Physiotherapy, Moscow, USSR); Skurikhina, L. A.; Skuratovich' A. A.; Avazian, A. A. *Vopr Kurortol Fizioter Lech Fiz Kul't* (2): 16-19; 1979 (11 refs).

The effects of therapeutic and experimental ultrahigh frequency (UHF) irradiation on spermatogenesis were studied in men and in rabbits, respectively. The therapeutic experiment involved UHF irradiation (40 W, 8-10 min/day, 3-10 sessions) of the testicles of 38 men (aged 21-50+ yr) with epididymitis (28 cases of acute epididymitis and 10 nonacute; 10/38 cases of gonorrhreal etiology). The ejaculate was examined in 19 patients 3-6 mo after treatment and in 11 patients 5 yr after treatment. No pathologic changes were observed and the numbers of motile spermatozoa were normal. Analysis of the catamnestic data showed no children in the families of six patients; no data were available on one patient. The findings indicate that UHF treatment did not interfere with the reproductive capacity of the patients. The experimental study involved the UHF irradiation (30 W, gap 1.5-2 cm, 6 min/day, 8 sessions) of the testicles and epididymis of 20 rabbits. Histologic sections

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of the irradiated organs were examined 1, 5, 10, and 30 days after treatment. Activation of spermatogenesis was observed 1 day after treatment. No histologic changes were observed after 5 days, and spermatogenesis returned to normal within 10 days of treatment.

6719 ELECTROMAGNETIC FIELD AND PSYCHOBIOLOGIC INFORMATION. (Cze.) Grunner, O. (Rehabilitacni oddeleni, Nemocnice s poliklinikou OUNZ, Havlickova 294, 790 00 Jesenik, Czechoslovakia). *Cas Lek Cesk* 118(40/41): 1221-1226; 1979 (34 refs).

Clinical and experimental studies on the psychobiologic effects of electromagnetic fields are reviewed. The human body is able to receive electromagnetic signs in the range of several tens to hundreds gamma (1 gamma=10⁻⁸ G). The organism is also able to emit information-carrying electromagnetic signals. The application of a homogeneous electromagnetic field (0.72 or 96 G, pulse length 66 msec, frequency 12 Hz) to the head for 1 hr was observed to alleviate migraine headaches. The response to the electromagnetic treatment was manifested in a normalization of the electrogram of the fingertips.

6720 EFFECT OF A CONSTANT MAGNETIC FIELD ON ELABORATION OF CONDITIONED REFLEXES OF MICE IN LOWLANDS AND HIGHLANDS. (Rus.) Ryskanov, T. (Kirghiz Medical Inst., Frunze, USSR); Abdullina, Z. M. *Zh Vyssh Nerv Delat* 29(2): 410-412; 1979 (9 refs).

The effect of a constant magnetic field of varying strengths (2,000 Oe, gradient 20 Oe/cm; 200 Oe, gradient 25 Oe/cm; and 20 Oe, gradient 1 Oe/cm, 2 hr/day for 10 consecutive days) on the elaboration of the conditioned escape reflex was studied in albino mice. The animals were placed in a T-shaped labyrinth and the effects of previous exposure to the magnetic field were investigated under flatland and highland conditions (3,200 m above sea level). The development of the conditioned reflex was inhibited at all intensities under flatland conditions; the inhibition was most pronounced at 2,000 Oe. In the group exposed to 20 Oe, inhibition of the conditioned escape reflex was not observed until the 6th day, indicating a summation effect. Under highland conditions at 20 Oe, inhibition of the escape reaction was observed only after the first 5 days. Under highland conditions, in the groups exposed to 200 Oe and 2,000 Oe, the animals developed the escape reaction more easily than the group exposed to 20 Oe or the control group. The results demonstrate that even though both constant magnetic field and highland conditions

have similar effects on the elaboration of conditioned reflexes, their effects are antagonistic when occurring simultaneously.

6721 PHYSIOLOGICAL AND BEHAVIORAL EFFECTS OF CHRONIC EXPOSURE TO 2450-MHz MICROWAVES. (Eng.) D'Andrea, J. A. (Dept. Electrical Engineering, Univ. Utah, Salt Lake City, UT 84112); Gandhi, O. P.; Lords, J. L.; Durney, C. H.; Johnson, C. C.; Astle, L. *J Microwave Power* 14(4): 351-362; 1979 (25 refs).

Long-Evans male adult rats (350-375 g) were exposed for 16 wk to 2.450-MHz continuous wave microwaves at an average power density of 5 mW/cm² (dose rate, 1.23 ± 0.25 mW/g) to assess the physiologic and behavioral effects of chronic microwave exposure. The electric field was parallel to the long axis of the holding cage and to that of the rat, resulting in maximal absorption of radiant microwave energy. The animals were exposed for 8 hr/day, 5 days/wk, for a total of 640 hr in a monopole-above-ground radiation chamber while housed in Plexiglas holding cages. Daily measures of body mass and of food and water intake indicated no statistically significant effects of microwave irradiation. Biweekly stabilimetric tests immediately after exposure revealed a significant depression of behavioral activity in 15 microwave-exposed rats as compared with 15 sham-exposed animals. Measures of locomotor activity based on revolutions of a running wheel, which were obtained during 12-hr periods between each 8-hr exposure, showed no significant effect of microwave irradiation. However, the overall mean number of wheel revolutions for microwave-exposed rats was approximately 30% greater than that for sham-exposed rats during the study. This may reflect attempts by the microwave-exposed animal to recover the loss of the increased metabolic load while not under exposure. Blood samples taken after 2, 6, 10, and 14 wk of microwave exposure indicated slight alterations of sulphydryl groups and of red and white blood cell counts. Measurement of the mass of the adrenals, heart, and liver at the end of the 16-wk exposure period as well as measurement of 17-ketosteroids in the urine at 1, 5, 9, and 12 wk of exposure revealed no indications of stress.

6722 MICROWAVE IRRADIATION AND AMBIENT TEMPERATURE INTERACT TO ALTER RAT BEHAVIOR FOLLOWING OVERNIGHT EXPOSURE. (Eng.) Gage, M. I. (Neurotoxicology Div., MD-74, Health Effects Res. Lab., EPA, Research Triangle Park, NC 27711). *J Microwave Power* 14(4): 389-398; 1979 (14 refs).

The interaction of microwave power density with ambient temperature was assessed in male Long-Evans

hooded rats (235 days old, 315-365 g) by measuring operant behavior after termination of overnight exposures. Each of 12 naive rats was trained to insert its head into a food cup for food pellets on a random-interval schedule of reinforcement. After performance stabilized, the rats were assorted into three groups of four animals each. Groups were matched for response rates. The rats were exposed in an electrically anechoic chamber under far-field conditions in groups of four animals each for 15.5 hr to continuous wave 2.450-MHz microwaves once every 6 nights. Each group was exposed to a given power density of 5, 10, or 15 mW/cm² for three times at an ambient temperature of 22°C, then three times at 28°C, and then once more at 22°C. The relative humidity was 50% during all exposures. Rats were sham irradiated the night before each microwave exposure. Behavior was tested daily after termination of microwave irradiation or after sham exposure. Exposure to microwaves at 22°C did not alter the rate or duration of responding behavior. However, behavior following 10- or 15-mW/cm² exposure at 28°C showed a marked decrement in overall performance, increased occurrence of long pauses between bursts of responding, and decreased numbers of reinforcers received by the animals. The results are interpreted as a transient debilitation of behavior that is produced by the interaction of a mild elevation of ambient temperature and microwave irradiation.

6723 PSYCHOSES IN RADIO WAVE DISEASE. (Rus.) Chudnovskii, V. S. (Dept. Psychiatry, Kazan' Medical Inst. Kazan', USSR). *Sov Med* (8): 111-115; 1979 (8 refs).

The case reports of three men with psychoses that developed during stages II and III of radio wave disease are presented. The three men were exposed occupationally to high-energy super-high frequency radio waves in the centimeter and 10-cm range for 10-19 yr. One patient was also exposed to ultrasound for the last 4 yr. Exposure was especially intense (10-12 hr/day) immediately before the onset of the radio wave disease. Weakness, fatigability, epicardia pain, palpitation, headache, sleeplessness, and irritability were the first symptoms. Neurosis, autonomic vascular dystonia, and thoracic radiculitis were diagnosed. Moderate disorders of the oculomotor innervation, nystagmus, tendon hyper-reflexia, reduced cerebral circulation or venous stasis, and retinal angiopathy were also found. The psychoses developed on a background of severe asthenia and were characterized by delirious disorders. The first psychotic attack developed abruptly in one patient in stage II radio wave disease. Emotional stability, hyperesthesia, asthenic syndrome, and hallucinations were diagnosed. The psychotic episode lasted about 1 mo, after which the patient developed partial amnesia. In the two other patients, psychotic disturbances developed after observation of such behavioral traits as reduced personality, euphoria,

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explosiveness, slight impairment of memory, and self-criticism. One patient suddenly developed a paranoid syndrome. The follow-up of the patients (2-7 yr) disclosed no signs characteristic of schizophrenia. The treatment of psychoses in radio wave disease is unspecific and is determined by the cardinal psychopathologic syndrome and by the somatic disorders.

6724 MICROWAVE PHOTOCONDUCTIVITY IN PLANT LEAVES. (Rus.) Deriabkin, V. N. (Moscow Physical Technical Inst., Moscow, USSR); Kireev, V. B.; Spachkov, M. P.; Trukhan, E. M. *Biotizika* 24(16): 1026-1029, 1979 (10 refs).

The superhigh frequency (SHF) photoconductivity of pea and *Tradescantia* leaves illuminated at 0.5-100 MW/cm² was studied at 10 and 1 GHz by measuring microwave photo-induced dielectric loss signals. All signals at both frequencies were linearly dependent on the white light intensity. The signal obtained for the fresh leaves at 10 GHz had a biphasic course with the major portion being negative at 20 C. Negative photoconductivity was found after heating above 50 C. A positive signal component appeared when the leaves were stored in darkness for approximately 30 min before illumination, and the entire signal was positive when the leaves were dried before the measurement. At 1 GHz, both the fresh and dried leaves gave similar positive signals, and moderate heating had no effect on the shape of the signal. Heating the leaves at 100 C for 10 min reduced the signal amplitude. It is suggested that the positive segment of the biphasic signal obtained for fresh leaves may be associated with conformational and charge changes of the photosynthesizing apparatus and with the photoconductivity. Heating of the leaf causes changes in the tissue electrolyte composition; as the contribution of the heating of the water diminishes, the positive signal appears more clearly.

6725 MICROWAVE TECHNIQUES IN FOOD PROCESSING. (Ger.) Reuter, H. (Institut fur Verfahrenstechnik, Bundesanstalt fur Milchforschung, Kiel, W. Germany). *Gordian* 80(1757): 44-50, 1980 (10 refs).

The general physical and biologic effects of microwaves and the use of microwave techniques for food processing are reviewed. The thermal effect of microwave radiation on the human body causes an increase in the body temperature only beyond a certain limit, depending on the environmental temperature, heat dissipation, and the surface irradiated. Exposed organs with high water content, such as the eyes, are especially at risk. Microwave ovens should not emit radiation during operation, and their opening during operation should be prevented in a fail-safe manner.

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6726 EFFECT OF SOME FACTORS OF PRE-EMERGENCE ELECTRICAL TREATMENT OF SPRING WHEAT SEEDS ON CROP YIELD AND ON THE NUTRIENT UPTAKE DURING DIFFERENT PHASES OF ONTOGENESIS. (Rus.) Izakov, F. Ia. (No affiliation given); Blonskaia, A. P.; Okulova, V. A. *Elektron Obrab Mater* 16: 59-64, 1979 (6 refs).

The effect of electrical treatment of spring wheat seeds under varying conditions on the crop yield and nutrient uptake of wheat plants seeds was studied. The seeds were treated in a constant corona discharge field (5 kV/cm, voltage 50 kV, distance between electrodes 10 cm, duration of treatment 5 sec) and plants grown from untreated seeds served as controls. The electrical treatment was carried out either in a vacuum or in open air, in which case ionization was possible. The crop yield was 2.410 kg/hectare for the controls, 2.940 kg/hectare for the group treated in air, and 2.840 kg/hectare for the group treated in a vacuum. Both electrical treatments increased the nitrogen, phosphorus, and potassium levels in the plants at different stages of ontogenesis, but seed treatment in air had a more pronounced effect than did treatment in a vacuum. At the stage of milky ripeness, the nitrogen level was 126.2% of the control after treatment in air and 118.7% after treatment in a vacuum. The phosphorus levels were 105.1% and 115.5%, and the potassium levels were 103.5% and 103.5%, respectively. When the electrical treatment was carried out in a nitrogen or an oxygen atmosphere, crop yield was 3.210 kg/hectare and 2.780 kg/hectare, respectively, versus 2.410 kg/hectare for the controls. At the stage of milky ripeness, nitrogen, phosphorus, and potassium levels were 152.5%, 173.5%, and 109.5% of the control values, respectively, for a nitrogen atmosphere and 118.7%, 89%, and 100%, respectively, for an oxygen atmosphere. When the grounded electrode was insulated with a coveyer belt, polyethylene, fiberglass, or polyvinyl chloride during the electrical treatment, the crop yields were 3.120, 2.950, 3.140, and 3.330 kg/hectare, respectively, versus 3.160 kg/hectare without insulation and 2.760 kg/hectare in the absolute control. For the insulated electrode experiments, the nitrogen levels in plants at the stage of milky ripeness were 118.7%, 118.7%, 100%, and 170%, respectively, while the phosphorus levels were 108%, 89%, 94.8%, and 105.1%, and the potassium levels were 109.5%, 109.5%, 100%, and 109.5%, respectively.

6727 USES OF ELECTROMAGNETIC WAVES IN FOOD TECHNOLOGY AND AGRICULTURE. (Fre.) Thourel, M. (Departement d'Etudes et de Recherches en Microondes, Centre d'Etudes et de Recherches de Toulouse (ONERA), Toulouse, France). *Rev Gen Elecfr* 88(11): 851-857, 1979 (no refs).

The uses of microwaves in food technology and agriculture are reviewed. The thermal effect of

microwaves can be used to dry, dehydrate, cook, bake, bleach, pasteurize and sterilize food products; to kill soil weed seeds; and to kill parasites in soil and food products. Results of one experiment demonstrate that microwave treatment at 2,450 MHz (to produce temperatures of 52°C) was effective for killing fungi and retarding the fermentation of must. Treatment at 27.12 MHz was effective in the destruction of insects in cereals and flour. The advantages of microwaves for the above uses, e.g., savings in energy, space, time, and manpower, are equalized by the relatively high cost of microwaves. The author predicts, however, that a reduction in cost will evolve over the next several years.

6728 CHANGES IN THE ELECTRICAL CONDUCTIVITY OF THE WHITE AND YOLK OF HENS' EGGS DURING THE EARLY STAGE OF INCUBATION UNDER THE EFFECT OF MAGNETIC FIELDS. (Rus.) Borodaikevich, D. T. (No affiliation given); Khananaev, L. I. *Biol Nauki* (4): 34-38; 1979 (10 refs).

The effect of a 60-min preincubation exposure to magnetic fields of various strengths on the electrical conductivity of the albumen and yolk of 534 eggs from White Leghorn hens was studied. The conductivity was measured from 12 to 96 hr of incubation at 500, 2,000, and 5,000 Hz. The eggs were transferred into the incubator 1-2 min after treatment. The field intensity was 50, 100, and 200 Oe in all experiments. Some eggs were exposed to a constant magnetic field (CMF, parameters not given), others to an alternating magnetic field (AMF, 50 Hz), and others to a pulsed magnetic field (PMF; pulse length, 220 msec, interval between pulses 20 sec). PMF and AMF increased the electrical conductivity of the albumen and yolk, while CMF decreased the conductivity compared with the untreated controls. PMF and AMF may accelerate the ion exchange, thereby increasing the electrical conductivity. The reduction of the conductivity due to CMF exposure may result from an inhibition of the ion exchange.

6729 THE EFFECTS OF LOW INTENSITY, EXTRA-LOW FREQUENCY ELECTROMAGNETIC FIELDS ON TIME PERCEPTION AND THE ELECTROENCEPHALOGRAM (ABSTRACT). (Eng.) Kercher, M. M. (Baylor Univ., Houston, TX 77025). *Diss Abstr Int B* 40(8): 3997-B; 1980 (no refs).

The effects of imposed electromagnetic fields on human behavior was investigated, with emphasis on the difference between field effects of various frequencies. Sixty male college students (aged 18-26 yr) were exposed to electric fields of four different frequencies (7, 14, 10, and 20 Hz) at 10 Vm. Each subject was exposed to a field and a no-field condition at a single frequency for approximately 25 min in each condition. Time estimation, as measured by the pro-

duction method, and an electroencephalogram (EEG) served as dependent measures. Subjects made 15 estimates of intervals of 5 and 9 sec in each field condition. Statistically significant differences were demonstrated between the field and no-field condition at 7 Hz; field estimates were shorter than no-field estimates. The differences were in the same direction at 14 Hz, but were not statistically reliable. There were no differences between field and no-field estimates at 10 Hz or 20 Hz. These results were explained in terms of the relationship of the experimental frequencies to the basic alpha frequency of 10 Hz. The frequencies that were not coincident with the alpha frequency, 7 Hz and 14 Hz, tended to have the predicted effect of shortening time estimates, though this effect was only significant for the 7-Hz field. The smaller effect at 14 Hz may have been due to a higher threshold for the higher frequency. The EEG was monitored constantly during the time estimations, but only that portion of the record that coincided with the actual time estimates was utilized to compute the percent of time alpha was present. For a given interval the alpha over 30 μ V was underlined and divided by the total length of the interval, yielding a percent of alpha for that interval. Analysis revealed no differences in the percent of alpha present in field versus no-field conditions for any of the experimental frequencies. It was felt that the lack of difference in the EEG between field and no-field conditions might reflect the inability of the particular method of EEG analysis utilized to tap any subtle field effects rather than a true state of no difference.

6730 AVIAN ORIENTATION AND NAVIGATION. (Eng.) Schmidt-Koenig, K. (Duke Univ., Durham, NC). (New York: Academic Press); pp. 29-152; 1979 (399 refs).

Laboratory and field experiments on avian orientation and navigation are reviewed, including the use of the earth's magnetic field as a compass. It appears that birds do not use the polarity of the magnetic field, but rather seem to evaluate the inclination of the field lines to the vertical. Avian magnetoreception also appears to be adaptable to different intensity ranges. As birds react to magnetic storms, which are small variations of the geomagnetic field, e.g., from 0.460 Oe to 0.465 Oe, the avian magnetic compass appears to be sensitive to changes of at least 0.005 Oe. Young pigeons seem to calibrate their sun compass by a learning process on the basis of their magnetic compass. Pigeons possibly also use the geomagnetic field for navigational information. Theoretical models of the physiologic mechanism of magnetoreception, such as utilizing the Hall effect in several different ways, have been suggested but never documented.

6731 THE RELATION OF TERATOGENESIS AND SURVIVAL IN *TENEBRIOS MOLITOR*

TO MICROWAVE IRRADIATION DURING METAMORPHOSIS. (Eng.) Green, D. R. (M.Sc. Dissertation, Washington Univ., MO 63130). A thesis presented to the Sever Institute of Technology of Washington University: 156 pp.: 1978 (34 refs).

The effect of microwave irradiation during metamorphosis of 2,214 pupae of the darkling beetle (*Tenebrio molitor*) on teratogenesis and survival was studied. A 2-hr irradiation of 1-day-old *Tenebrio molitor* pupae at a frequency of 9.00 GHz in an X-band waveguide increased the incidence of developmental abnormalities in resulting adults without correspondingly increasing pupal mortality at incident power levels below 160 mW. This was not observed when pupae were conventionally heated to the same temperatures experienced during irradiation. Pupae showing evidence of disease or trauma prior to irradiation ("nonideal pupae") exhibited the microwave effects to a greater extent than normal pupae ("ideal pupae"). The incidence of microwave related abnormalities and deaths did not appear to increase monotonically in the 40- to 160-mW incident power range, as it did outside this range. Microwave effects decreased in the vicinity of 80 mW, corresponding to a maximum temperature during irradiation of about 28°C for ideal pupae and 32°C for nonideal pupae. Significant evidence of microwave effects was not observed at ambient relative humidities above 35%, suggesting that pupal dessication is involved in the increased incidence of abnormalities for specimens irradiated as pupae. Although pupal mass following 2 hr of irradiation at 80 mW was within $\pm 1\%$ of the original mass, such a small change in water content may be responsible for the above observations. It is also possible that incompletely reversible changes in the permeability of the pupal cuticle may promote water loss at low ambient humidities following irradiation.

6732 THE BIOLOGICAL EFFECTS OF RADIO-FREQUENCY AND MICROWAVE RADIATION. (Eng.) Assenheim, H. M. (Associate Committee on Scientific Criteria for Environmental Quality, Environmental Secretariat, Natl. Res. Council Canada, Ottawa, Canada K1A OR6); Hill, D. A.; Preston, E.; Cairnie, A. B. [available through National Research Council Canada (NRCC/CNRC), Ottawa, K1A OR6, Canada. NRCC No. 16448]: 245 pp.: 1979 (299 refs).

Studies on the physical and biologic effects of radio frequency and microwave radiation are reviewed, as well as the applications of radio frequency and microwave radiation, dosimetry, and criteria for personnel exposure standards. Many of the low-level effects documented in the Soviet and Eastern Europe are generally not accepted by Western scientists. Epidemiologic studies suggest that at power densities $< 1 \text{ mW/cm}^2$ gross thermal effects are improbable. At power densities of 1-10 mW/cm^2 , weak

thermal effects may occur. East European and Soviet scientists claim that an asthenovegetative syndrome (e.g., nausea, headache, fatigue) occurs in this power density range because of effects on the nervous system; at this level, the changes are generally reversible. At power densities greater than 10 mW/cm^2 , distinct thermal effects occur with disturbances of the circulatory system and the thermoregulatory mechanism. In the 15-20 mW/cm^2 range, the onset of various syndromes occurs, depending on which organs are chronically exposed. Hypotension, fatigue, and changes in electroencephalograms and electrocardiograms have been noted. At power densities of greater than 20 mW/cm^2 , the onset of a hypothalamic syndrome or even radiation shock occurs according to Eastern scientists. The following effects are generally accepted by Western scientists: an increase in body temperature with the possibility of heat damage to the testis and some internal organs at power densities of 20-100 mW/cm^2 (corneal damage occurs at frequencies above 35 GHz); induced fever at power densities $> 100 \text{ mW/cm}^2$; and cataracts at power densities $> 150 \text{ mW/cm}^2$ if the eyes are irradiated at frequencies between about 2 GHz to over 10 GHz for longer than 1 hr. With regard to sources of radio frequency and microwave radiation, nondirectional broadcast stations, although considerably lower powered than many other sources, may prove to be the greatest potential hazard to man.

6733 PHYSICAL PLASMA IN BIOLOGICAL SOLIDS: A POSSIBLE MECHANISM FOR RESONANT INTERACTIONS BETWEEN LOW INTENSITY MICROWAVES AND BIOLOGICAL SYSTEMS. (Eng.) Zon, J. R. (Dept. Theoretical Biology, Catholic Univ. Lublin, Lublin 20-950, Poland). *Physiol. Chem. Phys.* 11(6): 501-506: 1979 (38 refs).

Resonant effects of microwaves in biologic systems are discussed in relation to the hypothesis that solid-state plasma occurs in organic semiconductors. Observed semiconductor properties of biologic material in vitro indicate possible involvement of semiconduction in biologic processes. Also, since solid-state plasma occurs in inorganic semiconductors, it is hypothesized that solid-state plasma similarly occurs in organic semiconductors. If continual plasma excitation does characterize biologic materials, then it is suggested that the resonant absorption and the positive biologic effects of microwaves (e.g., reduction of radiation damage and increase in survival ability) could be explained as being due to the supply of quanta of energy capable of sustaining the integrating plasma oscillations in the biologic system. On the other hand, the harmful effects of microwaves (e.g., inhibition of growth, repression of living activity, functional disturbances, morphologic changes, and decrease in survival ability) may conversely be explained in terms of suppression of plasma oscillations.

6734 RECOMMENDED PERMISSIBLE LEVELS FOR EXPOSURE TO MICROWAVE AND RADIOFREQUENCY RADIATION (10 MHz TO 300 GHz)—A PROPOSAL. (Eng.) Cornelius, W. A. (Australian Radiation Lab., Melbourne, Australia); Viglione, G. [Report No. ARL/TR009]: 25 pp.: 1979 (23 refs).

Maximum permissible levels for exposure to radio frequency and microwave radiation (10 MHz to 300 GHz) are proposed. The proposed levels are calculated from a "worst case" analysis of electromagnetic energy absorption based on thermal hazard considerations, and they include a significant safety factor. For whole-body exposure to continuous wave (CW) or pulsed (P) electromagnetic radiation (EMR) in the 10-MHz to 300-GHz frequency range, except as provided for some near field exposure (NFE) conditions, the maximum permitted time integrated exposure averaged over any 1-hr period is defined as "L" mW-hr/cm², where L has the following values for different frequency (f) ranges: L=5.4 - 0.365f + 0.0064f² for 10<f<30 MHz; L=0.2 for 30<f<130 MHz; L=0.2 + 0.00128 (f - 130) for 130<f<600 MHz; L=0.8 + 0.00029 (f - 600) for 600<f<3,000 MHz; and L=1.5 for 3,000<f<300,000 MHz. For whole-body exposure to CW or P EMR in the 10- MHz to 300-GHz range for periods of less than 1 hr, except as provided for some NFE conditions, the maximum permitted irradiance (I) averaged over any 1-sec period is 4 L mW/cm²; the peak pulse irradiance must not exceed 1,000 mW/cm². The time integrated exposure must not exceed L multiplied by the square root of the time interval T (expressed in hr) in mW-hr/cm² for any T less than 1 hr. Under certain NFE conditions, greater irradiance levels than those specified above may be tolerated. For whole-body exposure to CW or P EMR in the range of 10 MHz to 300 GHz, except as provided for certain NFE conditions, the maximum permissible field strengths are as follows: electric field strength (V/m) must not exceed the square root of I multiplied by 3.770, where I is expressed in mW/cm²; the magnetic field strength (A/m) must not exceed the square root of I divided by 37.7, where I is expressed in mW/cm². The derivation of the above limits does not include blood flow cooling effects; exposure limits derived from accurate blood flow cooling models may allow higher exposures.

6735 BIOHAZARDS OF MICROWAVE BEAMS FROM PROPOSED SATELLITE SOLAR POWER STATIONS. (Eng.) Gandhi, O. P. (Dept. Electrical Engineering and Bioengineering, Univ. Utah, Salt Lake City, UT 84112). *Based on a presentation at the Conference on Health Implications of New Energy Technologies held April 4-7, 1979 in Park City, Utah.* 22 pp.: 1979 (15 refs).

The proposed satellite solar power station (SSPS) is described along with high priority areas of research on its possible microwave bioeffects. In addition, the current state of knowledge of microwave biologic ef-

fects is reviewed. The SSPS is designed to convert incident solar energy to direct current (DC) power, which is then converted to microwave energy for beaming to a receiving antenna site on the ground. The microwave energy incident upon the receiving antenna (rectenna) elements is then converted back into DC power. The proposed SSPS microwave transmitting system is designed to operate at a frequency of 2,450 MHz, and the ground level microwave power density on the beam axis is estimated to be 25.2 mW/cm². In case of a failure of the phase control system, the peak intensity of the beam will drop to 0.003 mW/cm². Priority areas of research on the possible microwave bioeffects of the SSPS, as identified by the United States Department of Energy, include the following: response of airborne biota; immunologic/hematologic studies; teratogenic effects; perturbations in behavior resulting from the interaction of drugs with SSPS microwave radiation; central nervous system effects; quantification of the absorbed dose in man and animals for unipath and multipath exposure conditions characteristic of rectenna sites; and quantification of thresholds for microwave-induced febrile convulsions, microwave-induced work stoppage, and sensory detection.

6736 ELECTROMAGNETIC FIELDS AND RELATIVE SAR PATTERNS IN BILAYERED BIOLOGICAL TISSUE EXPOSED TO A CIRCULAR APERTURE APPLICATOR. (Eng.) Tsiang, H. K. (Ph.D. Dissertation, Dept. Electrical Engineering, Univ. Washington, Seattle, WA 98195). [available through Xerox Univ. Microfilms, Ann Arbor, MI 48106, Order No. 7917654]: 185 pp.: 1979 (30 refs).

The specific power absorption rate (SAR) in human tissues exposed to a direct-contact or an indirect-contact microwave diathermy applicator was theoretically investigated using dielectric simulated fat-muscle tissue. A circular aperture source with a TE₀₁ mode field distribution was assumed for the applicator in the theoretical formulation. The frequencies used were 750, 918.8, and 2,450 MHz, and the aperture size varied from 7 to 16 cm in diameter. The theoretical study was based on a Fourier-Bessel integral representation technique, and a Gauss-Legendre quadrature integration technique was used in the numeric computations. Limited thermographic experiments demonstrated the validity of the theory that accurately predicted the experimental results within a reasonable limit. It was found that the fat to muscle SAR ratio decreases with increasing diameter of the applicator aperture up to approximately 1 wavelength (λ) as measured in the fat (f). A damped cosine variation of SAR ratio as a function of aperture radius ranging from 0.5 λ to 3 λ occurs when the applicator is in direct contact with tissue. Although there is a slight increase of the SAR ratio when an indirect contact applicator is used, penetration depth remains about the same and edge hot spots on the tissue surface are eliminated. The effects of varying the frequency and

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aperture size on SAR patterns are similar to those observed for direct contact applicators. It is concluded that an indirect contact applicator of 1 lambda f with a TE₀₁ mode source distribution should be used to achieve optimally deep and selective heating in muscle tissue.

6737 BIOLOGICAL EFFECTS OF HIGH STRENGTH ELECTRIC FIELDS ON SMALL LABORATORY ANIMALS. (Eng.) Phillips, R. D. (Battelle Pacific Northwest Lab., Richland, WA 99352); Anderson, L. E.; Kaune, W. T. [available through National Technical Information Service, Springfield, VA 22161, Document No. DOE/TIC-10084]: 349 pp.; 1979 (12 refs).

An interim report on the biologic effects of 60-Hz electric fields on small laboratory animals is presented. The biologic parameters that are being studied include: hematology, serum chemistry, immunology, pathology, metabolic status and growth, bone growth, endocrinology, cardiovascular function, neurophysiology, development, and behavior. Exposure of rats and mice to 60-Hz vertical electric fields at a field strength of 100 kV/m for up to 120 days (~20.5 hr/day) resulted in few statistically significant and reproducible effects. Consistent, replicated effects were observed in experiments measuring synaptic excitability. Serum levels of corticosterone and testosterone appeared to be reduced in exposed animals, and significant reproducible effects were documented in several behavioral tests. The results of several experiments showed trends that suggested the possibility of decreased in vivo cell-mediated immunity and alteration in several hematologic parameters, e.g., higher white blood cell levels in mice exposed from conception to 77 days of age and higher red blood cell parameters in the 3rd generation of exposed mice. Studies are in progress to determine if the observed effects are transitory or permanent and to establish the relationship between the observed effects and the intensity/duration of exposure.

6738 HUMAN RESPONSES TO POWER-FREQUENCY EXPOSURES. (Eng.) Michaelson, S. M. (Sch. Medicine and Dentistry, Univ. Rochester, Rochester, NY 14627). In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 1-20; 1979 (42 refs).

A literature review of recent research on possible health effects of electric and magnetic fields on man and animals is presented, and studies on the biologic effects of electric fields from high voltage transmis-

sion lines are reviewed. Most recent laboratory animal studies are unsuitable for extrapolation to man due to insufficiencies in the study design. Most research on possible health effects in man have been clinical studies of longitudinal or cross-sectional design or isolated studies on human volunteers. Systemic studies to determine the possible effects of electric fields on linemen have been conducted in the United States and Canada. Isolated occupational studies have been reported in Canada, Spain, and the United Kingdom. Reports from Russia and Eastern Europe are based on surveys performed on substation personnel. Studies on small numbers of humans have originated in the U.S., Germany, and Sweden. In North America there are currently more than 200,000 circuit miles of overhead transmission lines rated at 138 kV or higher of which 14,000 miles constitute 500 kV. There are also several thousands of miles of 765-kV lines that have been operating since 1969. Typical values of maximum vertical electric fields at 4 feet above ground level under extremely high voltage transmission lines range from 5 to 9 kV/m. There is no evidence of harm to humans or animals from these high voltage lines. Aside from accidental contact electrocution, no occupational disease or deviation of general morbidity patterns has been reliably reported among high voltage workers. Subjective sensations such as induced-voltage microshocks on ground contact do occur in workers exposed to high voltage field gradients, and corona discharge from the sharp extremities of the body can occur in high voltage laboratory workers exposed to extremely high field gradients; however, these effects have not adversely affected health. Although it has been suggested that electric fields may act as stressors, electric fields of up to 20 kV/m have been demonstrated to induce no detectable stress response. There are also no indications of electrolyte shifts or metabolic disorders caused by electric fields acting on humans. It is concluded that electric fields of up to 20 kV/m and magnetic fields of up to 240 A/m, individually or in combination, do not present any persistent threat to health.

6739 THE HUMAN CONSIDERATIONS IN BIOEFFECTS OF ELECTRIC FIELDS. (Eng.) Mehn, W. H. (Medical Sch., Northwestern Univ., Evanston, IL 60201). In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp., pp. 21-37; 1979 (50 refs).

Studies on the biologic effects of electric fields from high voltage overhead transmission lines are reviewed. The experience of the electric utilities in the United States indicates that long-term exposure to electric fields at the levels that exist near transmission lines poses no hazard. This includes no long-

term effects attributable to induced currents on plants, animals, or humans, including those persons who work daily in the vicinity of energized high voltage lines. Soviet studies performed in 1966, 1968, and 1969 noted that workers servicing power transmission lines of 110 and 500 kV at open-air distribution and switching systems frequently complained of headache, heart pain, irritability, fatigue, apathy, sleeplessness, sleepiness, memory and attention-span disturbances, impairment of sexual potency, and various other disturbances primarily neurologic in nature. Functional disorders of the nervous and cardiovascular systems were also seen along with various disturbances of vegetative functions. These effects occurred only when the intensity of the electric field exceeded 5 kV/m, with the degree of the effect depending on the field intensity and exposure duration. More recent Soviet studies (1977) of human volunteers under natural conditions exposed to 330- and 750-kV overhead power lines have not shown any statistically significant changes in central nervous system functional condition, work ability, electrocardiogram, and numerous metabolic indices for exposure to a 5 kV/m electric field (2-hr exposure/day for 6 days) or a 12 kV/m electric field (30-min exposures, 3x/day, for 6 days). However, individuals exposed to fields of 15-16 kV/m (30-min exposures, 3x/day, for 6 days) complained of headache, fatigue, and irritability. An epidemiologic study to be conducted as part of a U.S.-Russia agreement in the fields of extra-high voltage and ultrahigh voltage transmission is described. It is concluded that at present, there is no known mechanism of action by which power frequency electric fields associated with power transmission can produce effects on living organisms.

6740 EVALUATION OF RESPONSES OF ELECTRICAL UTILITY COMPANIES TO ELECTROMAGNETIC RADIATION QUESTIONNAIRE. (Eng.) Holt, G. L. (Industrial Hygiene Branch, Tennessee Valley Authority, Muscle Shoals, AL). In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 38-41; 1979 (no refs).

A questionnaire was mailed to over 600 electrical utility companies in the United States and Canada during the spring of 1978 to determine the extent of employee complaints concerning health problems associated with working in or near the electromagnetic fields generated by electrical transmission lines and switchyards. Of 226 responses received, only about 2% indicated that complaints had been made by employees. Responses to questions involving personnel protective equipment indicated that for voltages of 345 kV and greater approximately 21% of the respondents used conductive suits and

11% used shielded buckets. For voltages of 500 kV and greater, 39% used conductive suits and 17% used shielded buckets. The survey also uncovered the fact that live-line maintenance is being conducted on 735-kV transmission lines.

6741 ENVIRONMENTAL EFFECTS OF 765-kV TRANSMISSION LINES. (Eng.)

Scott-Walton, B. (Center for Resource and Environmental Systems Studies, SRI International, Menlo Park, CA); Clark, K.; Holt, B.; Jones, D. C.; Kaplan, S.; Krebs, J.; Polson, P.; Shepherd, R.; Young, J. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 42-54; 1979 (3 refs).

Testimony given before the New York State Public Service Commission on the potential environmental and biologic effects of 765-kV overhead alternating-current transmission lines is reviewed. The testimony focused on the potential effects of audible noise, potential biologic effects of electromagnetic fields, potential for electric shock, effects on cardiac pacemakers, and potential effects of ozone produced by corona discharge. Although the fields generated by these lines are not strong enough to cause tissue heating, some witnesses described claims of increased serum triglycerides, accelerated bone fracture healing, altered psychomotor reaction times, synchronization of circadian rhythms, malaise, neurasthenia, and encephalogram changes in humans and primates. However, many of the experiments citing such effects involved electric and/or magnetic fields with strengths much greater than or with frequencies much different from ground-level fields under 765-kV lines. Some experts claimed that no biologic effects exist as a result of these fields. Witnesses agreed that adults will occasionally be startled by currents and sparks when they touch a large vehicle under or near 765-kV lines. The effects of such currents on children remain unresolved, but it is possible that currents beneath 765-kV lines might under rare circumstances approach the respiratory arrest current for children. Fields under 765-kV transmission lines may affect some cardiac pacemakers, although the testimony cited no cases of transmission line interference.

6742 ELECTRIC AND MAGNETIC FIELDS AS CONSIDERATIONS IN ENVIRONMENTAL STUDIES OF TRANSMISSION LINES. (Eng.) Lee, J. M. (Bonneville Power Admin., Portland, OR); Bracken, T. D.; Rogers, L. E. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in*

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Biological Effects of Nonionizing Electromagnetic Radiation V(1). September 1980

Richland, Washington. [available through National Technical Information Service, Springfield, VA 22161. Document No. CONF-781016]; 593 pp.; pp. 55-73; 1979 (44 refs).

The electrical and physical properties of a transmission line environment are described and the possible biologic effects of transmission line electric (E) and magnetic (H) fields on plants and animals are reviewed. The E and H fields of existing extremely high voltage transmission lines and the E field from a Bonneville Power Administration 1,200-kV prototype line appear to be too weak to cause adverse effects to low growing vegetation; however, trees that grow very close to transmission line conductors may be damaged by the corona caused by high electric field intensities. Transmission line E fields should have no adverse effects on soil invertebrates, owing in part to the low field intensities resulting from shielding effects of vegetation. Evidence from laboratory and environmental studies indicates that transmission line E fields can affect honeybees and possibly other insects. However, other studies report negative results. The strengths of E and H fields in water beneath transmission lines may be, as shown by laboratory studies, near the level of perception by some fish species. Although birds show an avoidance for perching on energized transmission conductors, they regularly nest and produce young in transmission towers with no apparent ill effects from E or H fields. Laboratory and environmental studies indicate that some birds can perceive low-level E fields; however, it seems unlikely that transmission line fields interfere with bird navigation or orientation. In most situations, small mammals on a transmission line right-of-way are exposed to negligible E field strengths because of shielding effects of vegetation. Environmental studies indicate that E and H fields do not result in adverse behavioral effects in large mammals. In comparison with documented effects of transmission line construction and maintenance activities that can be severe and result in direct mortality to plants and animals, the effects of E and H fields appear insignificant on the basis of environmental research to date.

6743 EFFECTS OF HIGH-VOLTAGE TRANSMISSION LINES ON HONEYBEES. (Eng.) Greenberg, B. (Bioconcern, Chicago, IL); Kunich, J. C.; Bindokas, V. P. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161. Document No. CONF-781016]; 593 pp.; pp. 74-84; 1979 (11 refs).

The effects of high voltage transmission lines on honeybees were studied. Honeybees in metal-free and conventional metal-containing hives were placed underneath a 765-kV transmission line. Ambient field

strengths at 1 m height were 6.6-7.1 kV/m. Within the hive bodies, electric fields were 0.6-4.5 kV/m in the nonmetal hives and 1.1-8.3 kV/m in metal-containing hives. With wire mesh shields in place, the electric fields in the hives were reduced to about 10 V/m, which was equal to the ambient condition in a control area, 400 m away. The magnetic field under the transmission line averaged 4.4×10^{-4} G for the vertical component and 7.1×10^{-4} G for the horizontal component. At the control site, the magnetic fields were one order of magnitude lower. Queen and brood production, hive wt, body wt of individual workers, in-hive temperature, honey moisture content, propolization of hive entrances, aggression, winter survival, hemocyte numbers, and blood proteins were among the parameters investigated. Bees in unshielded hives underneath the line were affected in several ways, with the effects being more pronounced in metal-containing hives: e.g., hive wt gain was almost zero ($p < 0.005$) owing to a near absence of honey; a lowered moisture content of honey ($0.025 < p < 0.05$); bees weighed less ($p < 0.01$); hive entrances were excessively but not completely propolized; there were fewer pupae ($p < 0.01$) but normal numbers of eggs, larvae, and queen cells; and all hives failed to survive the winter. In metal-free, unshielded hives, hive wt gain, bee wt, honey moisture content, and the numbers of eggs, larvae, pupae, and queen cells were all normal. Abnormal features in these hives were propolization of hive entrances (at a slower rate and lesser extent than in metal-containing hives), aggressive clusters of bees at lower-front hive corners, poor overwintering survival (78% mortality versus 14% in shielded counterparts underneath the line versus 9% for control hives), and a possibly higher hemocyte count.

6744 EXPOSURE OF PERSONNEL TO ELECTRIC FIELDS IN SWEDISH EXTRA-HIGH-VOLTAGE SUBSTATIONS: FIELD STRENGTH AND DOSE MEASUREMENTS. (Eng.) Lovstrand, K. G. (High-Voltage Res. Inst., Uppsala Univ., Uppsala, Sweden); Lundquist, S.; Bergstrom, S.; Birke, E. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161. Document No. CONF-781016]; 593 pp.; pp. 85-92; 1979 (4 refs).

Field strength and dose measurements were made at various locations in Swedish extra-high voltage substations where personnel were exposed to 50-Hz electric fields to determine the cumulative biologic effect of exposure. An instrument was designed that permitted continuous recording of the electric field dosage to which a person was exposed while working. The dosimeter measured the time of exposure to field strengths above 5, 10, and 15 kV/m of several work operations, e.g., servicing breakers and disconnectors, regular substation inspection, and

testing of insulator elements. Electric field strengths were mapped with a dipole-type field strength meter. Dosimeter measurements frequently showed that the dose was much lower than expected when personnel were working on the ground. This can be explained by the fact that work on the ground is performed on disconnected and grounded equipment or alongside shielding equipment frames where the local field strength is low. During routine inspections, which largely include moving across open areas between various components, the dosimeter readings agreed well with the dose estimated on the basis of field strength mapping. Work conducted on top of circuit breakers close to hot phases gave high exposure values; e.g., the accumulative exposure values (expressed as a percent of total exposure time) for electric field strengths of 10-15 kV/m and greater than 15 kV/m were 21 and 10%, respectively. Making inspection rounds and remaining in the substations when doing maintenance work often gave higher exposures than when working on disconnected and grounded components. Thus, people doing general maintenance work can be exposed to comparatively high fields.

6745 MONITORING OF PERSONNEL EXPOSED TO A 60-Hz ELECTRIC FIELD. (Eng.)
Deno, D. W. (General Electric Co., Pittsfield, MA). In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016] 593 pp.; pp. 93-108; 1979 (3 refs).

Two electric field exposure monitors, constructed to measure the time integral of the unperturbed electric field, were used to determine the exposure of personnel in high voltage installations to 60-Hz electric fields. The monitors were based on the principle that the current induced in a person is proportional to the unperturbed electric field and on the fact that the surface current density about the upper part of the body is suitably proportional to the unperturbed electric field to use as a measure. One monitor was used for hard-hat mounting above the visor, while a second more complicated device, which switches with logic the integration of the electric field into three categories of electric field intensity (0-5, 5-10, and >10 kV/m), was mounted with an armband. Accuracy of the monitors was limited by the local electric field stability about the measuring surface. Instability of the local electric field was dominated by hair, clothing, moisture, and individual body shape. A nominal accuracy of approximately +10% was achieved in practical tests for outdoor conditions. Values of individual exposure for people in high voltage installations were measured and were found to be much lower than the maximum exposure that could be obtained by multiplying the electric field strength in the work area by the total time of exposure.

6746 60-Hz ELECTRIC FIELD PARAMETERS ASSOCIATED WITH THE PERTURBATION OF A EUKARYOTIC SYSTEM. (Eng.) Miller, M. W. (Dept. Radiation Biology, Sch. Medicine and Dentistry, Univ. Rochester, Rochester, NY 14627). Carstensen, E. L.; Kaufman, G. E.; Robertson, D. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016] 593 pp.; pp. 109-116; 1979 (5 refs).

Roots of *Pisum sativum* (garden pea) were exposed for 7 days to 60-Hz electric fields ranging from 70 to 430 V/m in an aqueous medium whose conductivity was approximately 0.07 S/m to quantify the electric field parameters associated with the perturbation of a eukaryotic system. Corresponding current densities in the exposure medium associated with these field strengths ranged from 0.5 to 3.0 mA/cm². Root growth rate was examined for a random selection of seedlings assigned to one of two groups (exposed or control) that were concomitantly grown in the same tank where the growth medium was continuously circulated. Temperature in the exposure medium was held constant at 19 + 1 C. Exposure to 60-Hz fields greater than 290 V/m caused a reproducible reduction in the rate of root growth. The data pointed to a threshold for the effect at approximately 2 mA/cm² or 290 V/m. The maximum reduction in root growth rate (relative to controls, p < 0.01) occurred at the highest electric field strength of 430 V/m on the 1st and 2nd day after exposure. Comparable fields could not be obtained by exposure of the medium through air because the required fields would exceed the dielectric strength of air. Under conditions in which growth inhibition occurs, it is estimated that induced 60-Hz cell membrane potentials would be about 5 mV.

6747 EFFECTS OF EXTREMELY LOW FREQUENCY FIELDS ON SLIME MOLD: STUDIES OF ELECTRIC, MAGNETIC, AND COMBINED FIELDS, CHROMOSOME NUMBERS, AND OTHER TESTS. (Eng.) Greenebaum, B. (Div. Science, Univ. Wisconsin-Parkside, Kenosha, WI 53141); Goodman, E. M.; Marron, M. T. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016] 593 pp.; pp. 117-131; 1979 (14 refs).

Lengthening of the mitotic cycle and depression of the respiration rate after exposure of the slime mold *Physarum polycephalum* to 75-Hz continuous wave (CW), sinusoidal electromagnetic fields of 2.0 G and 0.7 V/m were significantly greater in magnitude than the corresponding changes produced after exposure

to either the electric field (0.7 V/m) or the magnetic field (2 G) independently or after exposure to both fields at 20% of the original strength. Exposure of the slime mold to modulated fields (minimum-shift keying modulation) at three different levels (0.7 V/m and 2.0 G, 0.14 V/m and 0.4 G, and 0.035 V/m and 0.1 G) produced roughly the same magnitude of lengthening of the mitotic cycle, even though the field levels varied by a factor of 20. This suggests the absence of a strong dose-response relationship. A similarity of the changes in the mitotic cycle length between the modulated and CW experiments suggests that the mechanism of action may not depend critically on the waveform producing the change. In general, respiration rate data supported the mitotic cycle data. Indirect measurements of chromosome numbers indicated that any difference in such numbers induced by exposure to the electric and magnetic fields was less than 6% ($p < 0.05$) in this polyplid organism.

6748 FIRING-PATTERN CHANGES AND TRANSMEMBRANE CURRENTS PRODUCED BY EXTREMELY LOW FREQUENCY FIELDS IN PACEMAKER NEURONS. (Eng.) Wachtel, H. (Dept. Biomedical Engineering, Duke Univ., Durham, NC). In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 132-146; 1979 (13 refs).

The minimum current densities of an extremely low frequency (ELF) field needed to perturb the firing of pacemaker neurons from the abdominal ganglion of the marine mollusc *Aplysia* were measured as a function of frequency and direction. These measurements were compared with the values of intracellularly injected currents needed to produce the same effect to examine ELF field effects in terms of the transmembrane currents that they are likely to produce in nerve cells. The threshold for firing pattern disturbance was measured for frequencies ranging from 0.1 to 1,000 Hz. Between 0.8 and 1.0 Hz, a one-for-one synchrony between firing rate and the injected current, in response to intracellular current, was achieved with very weak current strengths (down to 0.6 nA). The firing rate changes observed in neurons in response to extracellular field currents generally followed the same pattern with respect to frequency as they responded to intracellular current. The minimum thresholds for ELF values near the ambient firing rate, leading to one-for-one synchrony, for field currents (at 0.55 Hz) was $2.0 \mu\text{A}/\text{cm}^2$. In the case of the field current, the threshold was highly dependent on the direction of the current with respect to the neuron orientation. The transmembrane current density calculated from estimates of cell membrane area averaged about 1% of the field current density needed to produce the equivalent effect on the neuron firing pattern.

6749 THE ROLE OF CELL SURFACE POLARIZATION IN BIOLOGICAL EFFECTS OF EXTREMELY LOW FREQUENCY FIELDS. (Eng.) Sheppard, A. R. (J. L. Pettis Memorial VA Medical Center, Loma Linda, CA 92357); Adey, W. R. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 147-158; 1979 (30 refs).

A counterion polarization model was applied to consider the polarization of long, thin neural processes such as dendrites of brain tissue in extremely low frequency electromagnetic fields parallel or perpendicular to the long axis of the neural process. The degree of polarization depends on orientation of the incident field with respect to the length of the dendrite or axon, radius of the cylindrical surface, ion mobility, and temperature. The effect of the polarization on the dynamics of weakly bound ions suggests ways in which certain ions may have greatly reduced momenta and thus participate in quantum behavior (such as tunneling), which, under normal circumstances, is not possible for such massive entities. The analysis leads to the possibility that nonclassical behavior by protons or other ions could provide amplification mechanisms of the type so far observed only in the electron gas or Bose gas of non-biologic physical systems.

6750 THE DESIGN OF EXPOSURE SYSTEMS FOR STUDYING THE BIOLOGICAL EFFECTS OF 60-Hz ELECTRIC FIELDS ON SMALL PLANTS AND ANIMALS. (Eng.) Poznaniak, D. T. (Westinghouse Electric Corporation, Pittsburgh [East], PA); Johnson, J. G.; McKee, G. W.; Graves, H. B. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 159-171; 1979 (9 refs).

Design considerations involved in constructing exposure systems, which simulate the electrostatic environment of extra-high voltage (EHV) transmission lines, for studying the effects of 60-Hz electric fields on small plants and animals are discussed. The typical electrostatic environment of transmission was determined by analytic studies and verification through field measurements. Near ground level the EHV electrostatic field is predominantly vertical in orientation, and such conditions are easily simulated by using a simple parallel-plate exposure system. A horizontal electric field component is not necessary since for actual transmission lines this component rarely exceeds 30° of the vertical component. Further system specifications include: exposure levels

of up to 80 kV/m (e.g., an approximate safety factor of 5), housing within environmentally controlled chambers, multileveled design for simultaneous multiple-exposure areas, and sufficient electrode (grid) spacing (0.5-1.0 m) such that the experimental subjects do not unrealistically enhance the initially undisturbed uniform electric field. These design considerations hold for small plants and animals that do not exceed 12-25 cm in height. To ensure carefully controlled dosimetry, steps such as individual caging and ceiling restraints should be implemented. However, if a fundamental objective of the study is the determination of effects on the subject regardless of their classification as primary (i.e., direct electric field) or secondary (i.e., piloerection) effects, then natural living conditions should be permitted. Controlled laboratory studies of the biologic effects of 60-Hz electric fields on small plants and animals are being conducted with the latter design approach. The validity of the experimental results, however, is dependent on the accuracy with which the experimental exposure system simulates a transmission line electric field.

6751 PREDICTION OF DAMAGE SEVERITY ON PLANTS DUE TO 60-Hz HIGH-INTENSITY ELECTRIC FIELDS. (Eng.) Johnson, J. G. (Westinghouse Electric Corporation, Pittsburgh [East], PA); Poznaniak, D. T.; McKee, G. W. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]; 593 pp.; pp. 172-183; 1979 (11 refs).

Laboratory studies involving the exposure of 85 species of small plants to 60-Hz high-intensity electric fields indicated that plant tissue damage severity is dependent on leaf tip geometry and morphology. Fleshy, rounded, or blunt plant parts showed no damage in 50-kV/m fields, whereas plant parts with a pointed shape exhibited minor damage at field intensities of 20-22 kV/m. Tissue damage was limited to the aerial portions of the leaf tip. The rate of tissue damage development decreased with time such that total tissue damage achieved a finite limit. This limit was directly proportional to electric field intensity. Tissue damage had the same electric field inception level as visible corona discharges about the damaged parts. Using Peek's law for partial electric breakdown in nonuniform fields, a technique for predicting the extent of tissue damage on a given species was developed. This prediction method uses data on the enhancement of the electric field at the tip of the plant as a means for calculating the corona-inception level for the plant. Experimental data for more than 20 specimens of five small plants (corn, wheat, onion, Kentucky bluegrass, and Scotch pine) typically found near transmission lines were analyzed by the technique, and the validity of the method

for calculating levels of corona inception and damage inception in uniform electric fields was demonstrated. The method can be used with reasonable accuracy only if single plants are considered. Further work is needed to confirm the plausibility of the method, especially for large, tall plants.

6752 BIOLOGICAL EFFECTS OF 60-Hz ALTERNATING-CURRENT FIELDS: A CHESHIRE CAT PHENOMENON? (Eng.) Graves, H. B. (Dept. Biology, Pennsylvania State Univ., Univ. Park, PA); Long, P. D.; Poznaniak, D. T. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CCNF-781016]; 593 pp.; pp. 184-197; 1979 (7 refs).

Short-term (0-120 min) and long-term (6 wk) exposures of male CD-1 mice to 60-Hz alternating current fields of 0, 25, or 50 kV/m revealed only random patterns of difference in blood cell composition changes. The parameters that were studied included red and white blood cell (WBC) count, packed cell volume, hemoglobin concentration, and differential WBC count. The differences observed in the long-term studies included an elevated WBC count and a statistically significant increase in lymphocyte numbers in the 50-kV/m group. No significant effects on WBC and lymphocytes were observed in the short-term studies. Behavioral studies with domestic pigeons exposed for 15-sec periods to a 60-Hz field (21 kV/m at the center of the head region) demonstrated a significant ($p \leq 0.001$) suppression in peck rates when the electric field was turned on. Decreased pecking responses were not observed in three pigeons tested under field-on, shielded conditions. Thus, short-term behavioral responses indicative of awareness of very high intensity fields were demonstrated.

6753 EXPOSURE AND DATA-COLLECTION FACILITIES FOR CIRCADIAN STUDIES OF ELECTRIC FIELD EFFECTS UPON BEHAVIOR, THERMOREGULATION, AND METABOLISM IN SMALL RODENTS. (Eng.) Ehret, C. F. (Div. Biological and Medical Res., Argonne Natl. Lab., Argonne, IL); Sacher, G. A.; Langsdorf, A.; Lewis, R. N. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]; 593 pp.; pp. 198-224; 1979 (12 refs).

The design and construction of facilities to investigate the long-term (days, weeks) effects of ex-

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tremely low frequency electromagnetic fields on circadian and intradiel aspects of behavior, metabolism, activity, and thermoregulation in rats and mice are described. The basic exposure facility consists of circular parallel-plate electrodes separated by a distance of 30.5 cm. Fields are held uniform by a set of three guard hoops or rings spaced between the electrodes. Animals are exposed in glass or plastic cages in either a horizontal or vertical orientation to the field. Miniprobe measurements of field strengths within the cages revealed that the fields are highly uniform, homogeneous, and reproducible from cage to cage. The facilities have been tested at 60 Hz, and preliminary measurements indicate that reasonably accurate indirect measurements can be made of the moment-to-moment fluctuations of the total current in the animal as it moves about within the cage. There is no simple relationship between posture of the animal and total current. Dimensionally, the total current in the animal is an increasing function of the potential difference across the body of the animal and also an increasing function of the area that the animal projects on the ground plane. These two factors are somewhat in opposition, and as a result the current becomes a complicated function of the animal's shape. Current density increases as the animal assumes a more upright posture and as the cross-sectional area projected on the ground plane decreases. Thus, it may be possible to utilize lateral and vertical shadowgrams to obtain an estimate of the moment-to-moment variations of the average body current density. Noticeable input from the corona, ozone, or transformer hum was not observed at 60 Hz.

6754 A PROTOTYPE SYSTEM FOR EXPOSING SMALL LABORATORY ANIMALS TO 60-Hz VERTICAL ELECTRIC FIELDS: ELECTRICAL MEASUREMENTS. (Eng.) Kaune, W. T. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352). In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]; 593 pp.; pp. 225-240; 1979 (6 refs).

The electrical properties of a prototype parallel-plate exposure system for subjecting mice or rats to 60-Hz vertical electrical fields are described. In this system, the animals stand on and are in electrical contact with the lower plate. The system comprises two horizontal, planar (1.0 by 1.8 m) parallel metal electrodes spaced 0.58 m apart and placed in a 3.5-by-3.7-m grounded metal-screen enclosure. The upper electrode is energized and the lower grounded. The capacitance is 41 picofarads (pF) between the two electrodes and 68 pF between the upper electrode and the metal-screen enclosure. The current required to energize the system, the electric field at the surface and the horizontal electric field at the

lower electrode, and the effects on electric field uniformity of grounded conducting walls and plastic cages were measured. The electric field is 97% of the ideal parallel-plate value at the center of the lower electrode and is uniform to within 7.5% over a 0.5- by 1.0-m area of the lower electrode surface; over this area the estimated horizontal field components 10 cm above the lower electrode surface are less than 3% of the vertical component. The presence of a grounded wall close to the electrodes adversely affected field uniformity, but energizing both electrodes with equal magnitude but oppositely phased voltages relative to the room walls minimized wall-electrode interaction and improved field uniformity. The effect on uniformity of the electric field of grounded conducting walls and plastic cages was studied in three cage configurations: 1) a 4.8-mm-thick plexiglass sheet, 30 cm wide x 51 cm high, placed 10 cm above the lower electrode increased the floor-level field strength by 1%; 2) a 4.8-mm-thick a plexiglass wall, 51 cm wide x 10 cm high, reduced the field strength at its base by 2.5%; and 3) a complete 10 cm wide x 25 cm long x 10 cm high plexiglass cage with roof resulted in a 5% variation in field strength over the surface of the cage floor.

6755 1,000-kV PROJECT: RESEARCH ON THE BIOLOGICAL EFFECTS OF 50-Hz ELECTRIC FIELDS IN ITALY. (Eng.) Cerretelli, P. (Dept. Physiology IIII, Univ. Milan, Milan, Italy); Veicsteinas, A.; Margonato, V.; Cantone, A.; Viola, D.; Malaguti, C.; Previ, A. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]; 593 pp.; pp. 241-257; 1979 (19 refs).

Basic cardiovascular variables, blood morphology and chemistry, growth and fertility, teratology, and changes in resistance to induced infections were investigated in mice, rats, rabbits, and dogs exposed to 50-Hz electric fields of up to 100 kV/m for 30 sec-8 hr/day over periods of up to 2 mo as part of an international program on ultrahigh voltage (UHF) transmission (1,000 kV Project). The electric fields were induced between two 1.5- by 2-m steel plates. The bottom plate, on the floor of a room, was grounded, and the energized electrode was hung above the grounded plate at a height that could be adjusted by means of pulleys. Thus, the animals that were housed on the grounded electrode could be exposed to various field intensities, depending on the distance between the plates and the applied voltage. No effects of exposure to the 50-Hz fields were observed in any animals at field strengths below 10 kV/m. However, above this threshold value, significant changes in the fraction of neutrophils and lymphocytes were observed in both dogs and rats. The growth rate of rats exposed to 25 and 100 kV/m fields

was significantly lower than that of controls. The fertility of rats was not affected by exposures to 100 kV/m (8 hr/day for 48 days). The resistance in albino mice to induced infections was not influenced by exposures of up to 25 kV/m (8 hr/day for 42 days). No teratogenic effects were detected in rats exposed to 100 kV/m (8 hr/day for 48 consecutive days).

6756 POWER FREQUENCY ELECTRIC FIELDS AND BIOLOGICAL STRESS: A CAUSE-AND-EFFECT RELATIONSHIP. (Eng.) Marino, A. A. (VA Hosp., Syracuse, NY 13210); Cullen, J. M.; Reichmanis, M.; Becker, R. O. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]. 593 pp.; pp. 258-276; 1979 (36 refs).

The effects of 60-Hz electric fields on the extent of fracture healing in 27-day-old male Sprague-Dawley rats were studied to test the hypothesis that such fields can act as biologic stressors. The fractures were performed at the midshaft of the fibula, and the extent of healing was assayed 14 days thereafter on the basis of blind scoring of serial histologic preparations. The rats were housed individually in totally plastic enclosures. Both food and water were supplied on essentially the same equipotential plane as that occupied by the animals. Half of the rats were exposed to a 60-Hz electric field of 5,000 V/m, and the other half served as controls. At 14 days after fracture, the degree of healing manifested by the exposed animals was substantially less than that of unexposed controls. The exposed animals had new bone with much thinner trabeculae than the controls, an increased amount of cartilage throughout the callus, and a scarcity of new bone in the fracture, indicating a relatively immature stage of fracture repair. It was estimated that the 14-day field-exposed fractures resembled a normal fracture site at 10 days after fracture. The entire experiment was repeated, and the results were identical. However, when rats were exposed at 1,000 V/m in two replicate experiments, no differences were seen in the degree of fracture healing between exposed and control rats. It is concluded that the above results indicate that a 60-Hz field of 5,000 V/m is a biologic stressor.

6757 EFFECTS OF CHRONIC EXPOSURE TO A 60-Hz ELECTRIC FIELD ON SYNAPTIC TRANSMISSION AND PERIPHERAL NERVE FUNCTION IN THE RAT. (Eng.) Jaffe, R. A. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Phillips, R. D.; Kaune, W. T. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]. 593 pp.; pp. 297-325; 1979 (16 refs).

Richland, Washington. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]. 593 pp.; pp. 277-296; 1979 (11 refs).

The effects of a 30-day exposure of male Sprague-Dawley rats (77-91 days old) to a 60-Hz, 100-kV/m electric field on synaptic transmission and peripheral nerve function were studied. Superior cervical sympathetic ganglia, vagus nerves, and sciatic nerves were removed from urethane-anesthetized rats after sham or electric field exposure in a parallel-plate exposure system. The nerves or ganglia were placed in a temperature-controlled chamber and continuously superfused with a modified mammalian Ringer's solution equilibrated with 95% oxygen and 5% carbon dioxide. Synaptic transmission and peripheral nerve function were characterized by the following parameters and tests: amplitude, area, and configuration of the postsynaptic or whole-nerve compound action potential; conduction velocity and synaptic delay; accommodation, refractory period, strength versus duration curves; conditioning test response; frequency response; post-tetanic response; and high-frequency-induced fatigue. Rats exposed to the 60-Hz, 100-kV/m field showed increased C-fiber conduction velocity, decreased rate of fatigue, and shifts in strength versus duration and conditioning test response curves in comparison with unexposed controls. These results suggest that such electric field exposures may increase neuron excitability.

6758 CLINICAL PATHOLOGIC EVALUATIONS IN RATS AND MICE CHRONICALLY EXPOSED TO 60-Hz ELECTRIC FIELDS. (Eng.) Ragan, H. A. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Pipes, M. J.; Kaune, W. T.; Phillips, R. D. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]. 593 pp.; pp. 297-325; 1979 (16 refs).

Hematologic and serum chemistry parameters were examined in rats and mice exposed to 60-Hz unperturbed fields of 100 kV/m for 15, 30, 60, or 120 days. The conditions were designed to eliminate secondary field influences. The first study on female Swiss-Webster mice (74 days old) showed no consistent hematologic or serum chemistry changes attributable to electric field exposure. In some cases, statistically significant differences were found between exposed and sham-exposed mice, but these changes were never consistent either between replications or between different exposure periods. The second study involved female Sprague-Dawley rats (56 days old). No reproducible changes were observed in the 15-, 30-, or 60-day exposures.

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However, there was a statistically significant increase ($p<0.01$) in the replicate composites of platelet concentrations of rats exposed for 60 days. The composite leukocyte concentrations were also significantly greater ($p<0.05$) in exposed rats than in sham-exposed rats after 60 days of exposure; this apparent leukocytosis was due to an absolute increase in lymphocytes. However, this difference was due entirely to the marked difference in total leukocytes from the second replicate since values of both groups were almost identical in the first replicate. In addition, leukocyte concentrations in sham-exposed rats were significantly lower than those from either the exposed or cage-control groups of rats. Overall, it is concluded that, with the possible exception of elevated platelet concentrations at the 60-day exposure period, there were no consistent effects observed in clinical pathologic parameters in either mice or rats exposed to 100-kV/m electric fields for as long as 60 days.

6759 IMMUNOLOGICAL STUDIES WITH 60-Hz ELECTRIC FIELDS. (Eng.) Morris, J. E. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Ragan, H. A. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 326-334; 1979 (16 refs).

Humoral and cellular immune parameters were measured in male and female Swiss-Webster mice (about 75 days of age) who were exposed for 21 hr/day to a 60-Hz, 100-kV/m unperturbed electric field for either 30 or 60 days. There were no significant differences between electric field-exposed and sham-exposed mice in terms of serum immunoglobulins, complement levels, distribution of thymus-derived or bone marrow-derived lymphocytes, or primary antibody response to keyhole limpet hemocyanin. In one study of 60-day exposed mice, total leukocyte and lymphocyte concentrations in the blood were significantly lower ($p<0.02$ and $p>0.01$, respectively) in the electric field-exposed mice than in sham-exposed mice. However, in a replicate study, total leukocyte and lymphocyte concentrations were significantly higher ($p<0.01$ and $p<0.05$) in electric field-exposed mice than in sham-exposed mice. In general, no significant changes in humoral and cellular limits of the immune system were observed in mice exposed to the 60-Hz field.

6760 DEVELOPMENTAL TOXICOLOGY STUDIES WITH 60-Hz ELECTRIC FIELDS. (Eng.) Sikov, M. R. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Montgomery, L. D.; Smith, L. G. In: *Biological Effects of Extremely*

Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 335-347; 1979 (9 refs).

The effect of exposure to uniform 60-Hz, 100-kV/m electric fields (21 hr/day) on reproduction and on fetal and postnatal growth and development was investigated in Sprague-Dawley rats. In an initial experiment, exposure to the electric field for 6 days prior to mating did not influence the fertility or number of animals that mated of either males or females. Litter size, prenatal death, and the sex ratio were also not significantly affected by electric field exposure. Exposure continuing through 20 days of gestation also did not influence the morphologic integrity of the fetuses or their size. Continued exposure of the sires of these litters as well as of females that did not mate during the initial breeding period did not alter their subsequent breeding performance or the ability of females to implant and maintain a litter to 14 days of gestation. In two additional experiments involving exposure to the electric field during gestation and for the first 8 days of postnatal life (experiment 2) or during the last 5 days of gestation and the first 25 days of postnatal life (experiment 3), no significant detrimental effects on the growth or survival of the offspring or on their physical development were noted. Only a few measures of postnatal neuromuscular development showed statistically significant differences between sham-exposed and electric field-exposed rats. The only notable difference (occurring in experiment 2) was a greater percent of exposed offspring showing motile behaviors (movement, grooming, and standing) and a smaller percent showing the righting reflex at 14 days of age ($p<0.05$). However, on retesting at 21 days of age, the results for sham-exposed and electric field-exposed groups were indistinguishable. In experiment 3, the only measure that was significantly affected in electric field-exposed rats was negative geotropism ($p=0.03$).

6761 ENHANCED GROWTH IN PUBESCENT MALE PRIMATES CHRONICALLY EXPOSED TO EXTREMELY LOW FREQUENCY FIELDS. (Eng.) Grissett, J. D. (Naval Aerospace Medical Res Lab., Pensacola, FL 32508). In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 348-362; 1979 (4 refs).

One animal from each pair of 60 rhesus monkeys that were pair-matched by sex, age, and weight was exposed for 22 hr/day each day since 1975 to a 76-Hz electromagnetic field with a magnetic field strength

of 0.2 mtesla and an electric field strength of 20 V/m to determine the biologic effects of fields with the same waveform but greater magnitude than those generated by the Navy's proposed extremely low frequency submarine communications system. The electric field distribution in the exposure chambers was measured with a high-impedance electric field probe. The most significant finding was that exposed males gained weight at a faster rate than did control males. The difference in weight was not accompanied by a difference in bone-length measurements. The divergence in weight gain occurred only during the first year, and the difference in weight gained for the entire 147-wk period is only significant at $p=0.09$. During the first year, blood urea nitrogen and serum glucose levels were lower in exposed males ($p=0.05$ and $p=0.01$, respectively); however, values for both exposed and control males were within normal limits. The gamma-glutamyl transpeptidase level was lower in exposed males ($p=0.06$), and, though consistently lower in exposed females, the difference was not significant ($p=0.37$). In males the difference tended to increase slightly with time while the opposite was true in females. Levels of serum glutamic oxaloacetic transaminase, glutamic pyruvic transaminase, and creatine phosphokinase were significantly lower in exposed males during the first week of exposure ($p=0.05$). Significant differences were not evident thereafter, although glutamic pyruvic transaminase levels continued to be lower in exposed males ($p=0.14$). Both exposed and nonexposed control monkeys appear to be healthy. It is suggested that the basis for the observed effect of electromagnetic fields on the growth of male monkeys may be related to the difference in maturity of males and females at the start of the experiment.

6762 A SYSTEM FOR THE EXPOSURE OF MINIATURE SWINE TO 60-Hz VERTICAL ELECTRIC FIELDS: CURRENT STATUS. (Eng.) Kaune, W. T. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Allen, C. H.; Beamer, J. L.; Gillis, M. F.; Miller, M. C.; Phillips, R. D. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 363-378; 1979 (7 refs).

The construction of a facility for exposing 40 miniature swine to 60-Hz vertical electric fields is described. Originally, an overhead 4.6-m high electrode with four parallel 7.6-cm diameter conductors was built to generate ground-level, 60-Hz, vertical electric fields of 30 kV/m. Fiberglass pens were built inside a nonconducting building located under the electrode and within the electric field. The pen floors were of steel plate and electrically grounded. However, during the testing of this facility, it was

observed that as the electric field was interacting with and destroying certain parts of the building. The seam regions between adjacent panels and, subsequently, the panel interiors had become contaminated with water. Sufficient leakage currents existed to produce a significant distortion of the electric field and to damage the building. Thus, a new grid electrode, consisting of 21 conductors, was built inside the exposure building, with the height of the electrode being 2.29 m in the building's center and 1.70 m at the outer edges. The inside surfaces of the building were covered with metal screen that was electrically grounded, thus preventing exposure of the building to the electric field. The ground level electric field for this new arrangement is uniform to 5%. Enhancement of the electric field at the surface of a swine's body as a result of the lowered electrode height is less than 5%. The electric field total harmonic distortion is 0.5%. No ozone concentrations above ambient background levels in the building are generated by the energized electrode.

6763 MAGNETIC FIELD EFFECTS ON HUMANS: EPIDEMIOLOGICAL STUDY DESIGN. (Eng.) Budinger, T. F. (Donner Lab., Univ. California, Berkeley, CA 94720); Wong, P. D.; Yen, C. K. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 379-399; 1979 (3 refs).

The design of a retrospective epidemiologic study of the health effects of stationary and low-frequency alternating magnetic fields on humans is described. The study population will comprise 1,000 cyclotron and bubble chamber workers who have been occupationally exposed to magnetic fields of at least 5 G in magnitude for 8,000 G-hr during their working careers. The study includes acquisition of medical data from exposed subjects as well as from 1,000 matched controls from eight facilities in North America. Studies of the latent effects from acute and very high exposures will involve subjects who have worked in fields greater than 400 G at facilities such as calutrons during World War II. In addition, individuals involved in calibrating large magnets and individuals exposed to very high fields around bubble chambers will comprise this high-field exposure population. The study will include identification of exposed personnel and controls, the use of exposure information questionnaires, medical record encoding, estimation of magnetic field exposures by field measurements, computer modeling, and data analysis. Based on a sample size of 1,000 exposed subjects, it is estimated that a 50% increase in the prevalence of cardiovascular disease or cancer will be required before a firm conclusion can be made that there is a health effect from these magnetic field exposures.

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6784 FERROMAGNETISM IN FRESHWATER BACTERIA. (Eng.) Blakemore, R. P. (Dept. Microbiology, Univ. New Hampshire, Durham, NH); Frankel, R. B.; Wolfe, R. S. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 400-407; 1979 (5 refs).

Magnetotactic bacteria of the unclassified *Spirillum* type were isolated from swamp water and were cultured in the magnetic and nonmagnetic state. Cells of the magnetic *Spirillum*, but not of the nonmagnetic form, contained chains of crystals similar to those found previously in other magnetic bacteria of marshes and bogs. Energy dispersive x-ray analysis indicated that the magnetic cells had a significantly higher iron content than nonmagnetic cells. Atomic absorption spectrophotometry of acid-digested whole cells indicated that 1.5% of the dry weight of magnetic bacteria was iron; this value was 13 times that for nonmagnetic cells. Values for nonmagnetic cells were only slightly higher than published for other heterotrophic bacteria. These results suggested that iron was localized in the crystals of magnetic bacteria. When the Mossbauer spectrum for magnetic cells was compared with published spectra of magnetic and nonmagnetic iron-containing substances, the spectrum for magnetic cells resembled most closely the spectrum of magnetite. Pure magnetite was analyzed under similar conditions, and minor differences in the two spectra were observed. These differences may relate to differences in the types of samples (i.e., magnetite in biologic material versus pure stoichiometric magnetite) or may indicate the presence of additional iron-containing substances in magnetic cells.

6785 RESPONSE OF AGAROSE SOLUTIONS TO MAGNETIC FIELDS. (Eng.) Kalkwarf, D. R. (Physical Sciences Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Langford, J. C. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 408-418; 1979 (14 refs).

The effects of homogeneous magnetic fields of 0 and 1 tesla (T) on the gelation of electrophoresis-grade agarose and on the properties of the resulting gel were examined. Gelation temperatures of aqueous 1.4% agarose solutions increased with magnetic field strength from 37.4 ± 0.2 C at 0 T to 38.8 ± 0.2 C at 1 T. Gels of 1.4% agarose formed at 1 T were 7 \pm 3% more permeable to bacterial deoxyribo-

nucleic acid than gels formed at 0 T. Gels formed at 1 T melted at 1.7 ± 1.0 C higher than those formed at 0 T. These results indicate that agarose is selectively oriented in liquid solution by large magnetic fields and suggest that the same type of interaction may lead to magnetic effects in tissues rich in the structurally related mucopolysaccharides

6786 IN VITRO EVALUATIONS OF STATIC MAGNETIC FIELDS. (Eng.) Frazier, M. E. (Biology Dept., Battelle Pacific Northwest Lab, Richland, WA 99352); Andrews, T. K.; Thompson, B. B. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 417-435; 1979 (28 refs)

Cultures of various cell lines were exposed to static magnetic fields of 0.1-1.0 tesla (T) to determine if there was a reproducible effect on cell morphology or physiology. In one group of studies, the cell lines L929, WI38, monkey kidney cells (VERO), and Syrian hamster embryo cells were exposed in the frozen state to 0.5 or 1.0 T for 4, 8, or 24 hr, they were then thawed and grown in culture by standard tissue-culture techniques. Magnetic fields of up to 1.0 T for 24 hr produced no consistent effects on cell viability, growth rate, cell size, morphology, or transformation. In another set of experiments, VERO cells were continuously exposed to 0.1 or 0.3 T for up to 20 passages (approximately 80 cell doublings) in culture. The only effect observed was a change in colony-forming efficiency of cultures exposed to 0.3 T. This appeared to be the result of increased cell clumping rather than magnetic-field-induced inhibition of cell division. However, this cell clumping may have been related to the magnetic field exposure

6787 EFFECT OF CONSTANT AND ALTERNATING MAGNETIC FIELDS ON TUMOR CELLS IN VITRO AND IN VIVO. (Eng.) Chandra, S (Service Therapeutic Radiology, VA, Edward J. Hines Jr. Hosp., Hines, IL); Stefani, S. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 436-446; 1979 (19 refs).

The effect of constant magnetic fields (CMF) up to 1.0 tesla (T) and of alternating (60-Hz) magnetic fields (AMF) up to 0.16 T on in vitro and in vivo tumor growth was investigated. In one set of experiments cultured cells derived from a Burkitt lymphoma and a human

bronchogenic carcinoma were exposed for 1 or 2 hr to various strengths of the CMF. Some cultures received a single exposure, while others were exposed daily for 3 days. Tumor growth was not affected in either cell line at CMF strengths up to 1.0 T. In another series of experiments, transplantable mouse mammary tumors subcutaneously implanted into syngeneic hosts were exposed to various CMF strengths (0.1-1.0 T) or to a 0.16-T AMF for 45-60 min/day for 3 or 4 days after tumor size had reached approximately 8-10 mm in diameter. Neither the CMF nor the AMF had any effect on tumor growth *in vitro*, *in vivo*, or when inhomogeneity of the magnetic field was introduced.

6768 AN ENVIRONMENTALLY CONTROLLED SYSTEM FOR EXPOSURE OF MICE TO LARGE DIRECT-CURRENT MAGNETIC FIELDS. (Eng.) Decker, J. R. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Kuffel, E. G.; Mahlum, D. D.; Sikov, M. R.; Harris, C. P. *In: Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Information Service, Springfield, VA 22161, Document No. CONF-781016] 593 pp.; pp. 447-461, 1979 (3 refs).

An environmentally controlled system for exposing mice to vertically oriented direct current magnetic fields is described. The system is designed to expose mice in sufficient numbers for adequate statistical evaluation to magnetic fields similar to or greater than those to which man is expected to be exposed in the operation of a 5,000-MW tokamak-type fusion power reactor. The exposure system was designed to minimize artifactual or masking effects. Two closed chambers are constructed so that sham-exposed and exposed mice (5 groups of 10 mice each) can be maintained under the same ambient environmental conditions with controlled temperatures, airflows, and lighting, and be provided with food and water. The chambers are mounted into two identical water-cooled, beam-bending magnets capable of producing a maximum vertical field of 1.5 tesla with an alternating current ripple of less than 0.0002% and a drift component of about 0.02% the nominal value. One magnet is energized to produce the desired field, and the other serves for sham exposure. The magnetic field can be automatically ramped on and off to simulate the cycling of a tokamak reactor. With the use of a step-function on-or-off signal, the slightly underdamped field has a minimum rise time of 2.4 sec and a minimum fall time of 15.3 sec. Better control of room temperature and chamber humidity is suggested to improve the system design.

6769 DEVELOPMENT OF MICE AFTER INTRAUTERINE EXPOSURE TO DIRECT-

CURRENT MAGNETIC FIELDS. (Eng.) Sikov, M. R. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Mahlum, D. D.; Montgomery, L. D.; Decker, J. R. *In: Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016] 593 pp.; pp. 462-473, 1979 (9 refs)

Gravid Swiss-Webster mice of known gestational age were exposed either to a homogeneous 1-tesla (T) or to a gradient (2.5 T/m) direct current magnetic field with a maximum strength of 1 T to determine the effects of intrauterine exposure on subsequent prenatal or postnatal development and growth. Experimental animals were housed in environmentally controlled chambers that were mounted within the bore of a beam-bending magnet. sham-exposed control mice were housed under identical conditions in a nonenergized magnet. For studies performed with the homogeneous field, the exposure chambers were centered on the poles of each magnet. Two replicate experiments were performed by using exposure on 0.5-7, 6-15, 10-18, or 0.5-17 days of gestation (dg) for prenatal evaluation and on 6-18 dg for postnatal evaluation. A second series of studies was performed using gradient field exposures (with one side of the chamber between the magnetic poles) on 0.5-7 or 0.5-18 dg for prenatal and 0.5-17 dg for postnatal evaluation. Overall, it appeared that no developmental effects were produced under the above exposure conditions. However, the number of mated mice that were found to be pregnant was lower than customarily found, and this resulted in inadequate litters per replicate to test for interreplicate differences. Even when the data from the two replicates were pooled to give a larger group size, this was usually inadequate for unequivocal statistical analyses, especially in view of the marked variability between litters.

6770 DOMINANT LETHAL STUDIES IN MICE EXPOSED TO DIRECT-CURRENT MAGNETIC FIELDS. (Eng.) Mahlum, D. D. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Sikov, M. R.; Decker, J. R. *In: Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington.* [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016] 593 pp.; pp. 474-484, 1979 (7 refs)

To evaluate the possibility that magnetic fields may induce mutations, groups of 10 male Swiss-Webster mice were exposed in the gap of an excited, beam-bending magnet (or were sham-exposed in a nonexcited magnet) to a static, homogeneous magnetic field of 1.0 tesla (T) for 28 days (group 1), to a static

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gradient field (2.5 T/m) for 28 days (group 2); or to a time-ramped, gradient field (2.5 T/m) for 42 hr (group 3). Following exposure, the group 1 and 2 males were bred with females of the same strain for 4 wk. Group 3 males were bred for 7 consecutive wk. Females were replaced weekly and were killed 10 days after separation from the males. The incidence of dominant lethal mutations, calculated from differences in the number of early resorptions or mean litter size, was not affected by any of the above exposure regimens. There were small differences between exposed and control groups in the total number of offspring produced, i.e., males exposed to homogeneous fields sired fewer total offspring than did nonexposed, whereas males exposed to either steady or pulsed gradient fields sired more offspring. In all cases, the differences between exposed and control groups were due to differences in the number of pregnant females, and it is unclear whether these differences are due to magnetic field exposure or represent normal variability. In another study where better breeding performance was obtained with Hilltop Swiss-Webster mice exposed to a time-ramped, gradient field (2.5 T/m) for 42 hr, the frequency of early resorptions was consistently higher in the exposed than in the sham-exposed group. However, the difference was not statistically significant by a chi-square test for any single week of breeding. When the difference between frequencies was tested over the entire breeding period (8 wk), the result was significantly different ($p < 0.05$).

6771 ELECTRICAL PARAMETERS OF THE HIGH-VOLTAGE DIRECT-CURRENT TRANSMISSION-LINE ENVIRONMENT. (Eng.) Bracken, T. D. (Bonneville Power Admin., Vancouver, WA). In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp., pp. 485-500, 1979 (17 refs).

Ground-level electrical parameters of high-voltage, direct-current (HVDC) transmission lines handling up to ± 600 kV are discussed, and HVDC is contrasted with extra-high-voltage, alternating current (AC) transmission lines. Three parameters are required to describe the complex electrical environment near an HVDC transmission line: electric field, space-charge density, and ion current density. Wind is a significant factor in determining the magnitude of the HVDC electrical parameters at ground level. The wind- and corona-induced dynamic quality of the parameters requires long-term averages for an adequate description. Field measurements undertaken at the Dalles HVDC test line of the Bonneville Power Administration indicated some typical values under low wind conditions for simultaneously measured field strength, ion current density, and charge density are

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20 kV/m, 40 nA/m², and 12 nC/m², respectively. These measurements demonstrated the feasibility of quantifying the HVDC electrical environment of any line. Proximity effects within the HVDC transmission line environment generally occur less frequently and with less severity than analogous AC effects.

6772 OZONE FIELD STUDIES ADJACENT TO A HIGH-VOLTAGE DIRECT-CURRENT TEST LINE. (Eng.) Droppo, J. G. (Atmospheric Sciences Dept., Battelle Pacific Northwest Lab., Richland, WA 99352). In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland, Washington*. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp., pp. 501-529, 1979 (17 refs).

Ozone concentrations attributed to corona losses were measured as a primary indicator of oxidant levels at a Bonneville Power Administration high-voltage direct-current (HVDC) test facility. The measurements indicated that environmental ozone levels from HVDC transmission lines, even under worst-case conditions, are reasonably well predicted by extrapolating ozone production rates from wind-tunnel tests. This confirmation of the ozone production rates is based on agreement between observed and predicted ozone plume parameters during precipitation conditions. The magnitudes of changes in ozone concentrations attributable to energized conductors were small for all weather conditions. For fair weather conditions the levels were not detectable in the natural variability of ambient ozone. The worst-case plume produced a 10-parts/billion increase for low-wind and precipitation conditions, with the monitor being 26 m from the conductor centerline and the line being operated at ± 500 kV with 70 mA of corona current. The surface level increase of ozone was less but of the same order of magnitude. This high value and extended vertical distribution are attributed to the long fetch created by winds nearly parallel to the conductors. A roving-profile measurement technique proved to be an effective method for defining the low concentrations of ozone emission from HVDC transmission lines. The origins of ozone plumes were identified in a reliable and consistent fashion as a result of the sensitivity of this method.

6773 MUTAGENIC EFFECTS OF HIGH-STRENGTH ELECTRIC FIELDS. (Eng.) Hungate, F. P. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352), Fujihara, M. P., Strankman, S. R. In: *Biological Effects of Extremely Low Frequency Electromagnetic Fields. Proceedings of the Eighteenth Annual Hanford Life Sciences Symposium held October 16-18, 1978 in Richland*

Washington. [available through National Technical Information Service, Springfield, VA 22161, Document No. CONF-781016]: 593 pp.; pp. 530-537; 1979 (3 refs).

Three different bacterial test systems and *Drosophila* pupae were exposed to direct current electric fields at strengths of up to 800 kV/m to investigate the possible mutagenic effects of such fields. An exposure system was developed for exposing small organisms to large electric fields. Overnight exposure of *Salmonella* strain TA-100 to these fields resulted in a significant ($p=0.01$) increase in the frequency of mutants compared with unexposed control cells. This strain mutates primarily by base exchange. In contrast, *Salmonella* strain TA-98, which mutates primarily by frameshift, failed to show any significant differences in frequencies of revertants after exposures at similar field strengths. A significant increase in the frequency of mutant-type colonies ($p<0.01$) was also observed for *Photobacterium fisheri* (tested for resistance to tetracycline) under similar exposure conditions. Data on the induction of sex-linked recessive lethal mutations in 1-day-old *Drosophila* pupae exposed for 3 days in a 185-kV/m field were inconclusive.

MEETING ABSTRACTS

6774 MICROWAVE-INDUCED HYPERTHERMIA: AN EXPERIMENTAL ADJUNCT TO BRAIN TUMOR THERAPY (MEETING ABSTRACT). (Eng.) Samaras, G. M. (Sch. Medicine, Univ. Maryland, Baltimore, MD 21201); Salzman, M.; Cheung, A. Y.; Taylor, L.; Robinson, J. E.; Scott, R. M.; Slawson, R. G. In: *Proceedings of the International Symposium on Multidisciplinary Aspects of Brain Tumor Therapy held June 8-10, 1979 in Brescia, Italy*. p. 27; 1979 (no refs).

Two approaches for the use of microwave-induced hyperthermia as an adjunct to brain tumor therapy are described. The first approach employs an implantable miniature coaxial cable (outer diameter, 1.83 mm) configured as a sleeve antenna. Powered by a 2.450-MHz diathermy unit, it generates a roughly ellipsoidal heating pattern. Thermal fields at 24 sites were mapped in normal feline brains. The resultant thermal fields, 2 cm below the cortical surface, were controllable to fractions of a centimeter, were reversible to baseline values within 2 min of power cutoff, required only 6-10 W for production, and had no effects on core temperature and various other physiologic responses. The second approach employs a dual microprocessor controlled multiplexing control system that permits superposition of multiple beams of microwave radiation. Miniature microwave antennae external to the scalp are employed with cross-sectional radiating apertures of 1.5 cm x 0.75 cm operating at a frequency of 915 MHz. Preliminary simulation experiments in phantoms and two beam measurements in normal feline brains in-

dicated that as few as four beams can produce a thermal gradient potentially lethal to a central tumor while leaving intervening tissue at a near normal temperature.

6775 MICROWAVE THAWING OF CANINE KIDNEYS (MEETING ABSTRACT). (Eng.) Holst, H. I. (Univ. Pennsylvania, Philadelphia, PA 19104); Lehr, H. B.; Ketterer, F. D. *Cryobiology* 15(6): 723-724, 1978 (no refs).

A unilateral kidney was removed from each of 16 anesthetized dogs (15-20 Kg body wt) perfused, frozen, thawed by 2.450-MHz microwaves, and reimplanted as an autograft in the neck of the animal. Four kidneys were perfused, frozen, and thawed as described by Guttmann and 12 were perfused with a modification of perfusates utilizing Haemeccel and helium, frozen at 1-2 C/min in a silicone bath, and thawed with bursts of 2.450 MHz. All four kidneys prepared by Guttmann's technique necrosed. Of the remaining 12, 5 partially survived reimplantation. All surviving kidneys were similar in that arteries, veins, pelvis, and ureters survived, while cortex and medulla were almost completely replaced with scar tissue. Two of these kidneys were stored for 1 wk at +95 C before thawing and reimplantation.

6776 EFFECT OF MICROWAVE RADIATION ON ACUTE MYOCARDIAL ISCHEMIA IN CATS (MEETING ABSTRACT). (Eng.) Galvin, M. J. (Natl. Inst. Environmental Health Sciences, Research Triangle Park, NC 27709); McRee, D. I. *Fed Proc* 39(3, Part 2): 989, 1980 (no refs).

The effect of local microwave radiation with 2.45 GHz on the course of myocardial ischemia (MI) was investigated in cats. MI or sham ischemia was induced in cats by occlusion of the left anterior descending coronary artery, and the hearts were exposed to either microwaves (30 mW/g, absorbed energy) or sham irradiation immediately after occlusion. The cats were monitored for 5 hr following artery occlusion. The specific absorption rate of microwaves was determined directly from the time-temperature profile of irradiated myocardium using a Vitek temperature probe. Mean arterial blood pressure (MABP), cardiac output (CO), heart rate (HR), plasma and myocardial creatine phosphokinase (CPK), and S-T segment were not altered by microwaves in control cats. The animals with MI plus microwave exposure and the cats with MI only had comparable values of MABP (124 versus 125 mmHg), CO (52 versus 59 ml/min/kg), HR (124 versus 123 beats/min), plasma CPK (8.5 versus 9.0 International units/mg protein), and S-T segment (0.60 versus 0.63 mV) at 5 hr post-occlusion. In summary, 5-hr microwave exposure had no effect either beneficial or exacerbative on the response of cats to acute myocardial ischemia.

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6777 THE EFFECT OF 2,450 MHz MICROWAVE RADIATION ON MAST CELLS (MEETING ABSTRACT). (Eng.) Ortner, M. J. (Natl. Inst. Environmental Health Sciences, Research Triangle Park, NC 27709); Galvin, M. J. *Fed Proc* 39(3, Part 2): 989; 1980 (no refs).

See Current Literature 6801 for description of this article.

6778 PHYSIOLOGICAL RESPONSE TO ACUTE MICROWAVE EXPOSURE DEPENDS ON THE CIRCADIAN RHYTHM (MEETING ABSTRACT). (Eng.) Lotz, W. G. (Naval Aerospace Medical Res. Lab., Pensacola, FL 32508). *Fed Proc* 39(3, Part 2): 989; 1979 (no refs).

To determine if the increase in circulating cortisol levels resulting from acute exposure of rhesus monkeys to 1.29 GHz microwave radiation (threshold intensity of 38 mW/cm²; 3.2 W/kg absorbed) is affected by the circadian rhythm, identical exposures were carried out at two different phases of the circadian cycle. Rectal temperature and plasma cortisol levels were determined hourly in three adult male rhesus monkeys before, during, and after an 8-hr exposure to pulsed microwave radiation, 1.29 GHz, over a total time period of 24 hr (lights on 0600-2200). Animals were exposed from 1200-2000 (day) or from 2200-0600 (night) to far-field conditions in an anechoic chamber at average incident power densities of 0 (sham) or 38 mW/cm². Rectal temperature increased an average of 1.5 and 2.0 C for the day and night exposures, respectively, although the absolute temperature reached was less during the night exposures (38.8 versus 39.3 C). Increased cortisol levels were observed in two of the three monkeys during the day exposures, but no difference was found between exposed and sham-exposed cortisol levels during night exposures. These results indicate that the physiologic response to acute microwave exposure is influenced by the circadian rhythm, but the mechanism of this interaction is unclear.

6779 GENETIC CONTROL OF MICROWAVE-INDUCED EFFECTS ON THE IMMUNE SYSTEM (MEETING ABSTRACT). (Eng.) Schigel, C. J. (Naval Medical Res. Inst., Bethesda, MD 20014); Woody, J. N. *Fed Proc* 39(3, Part 1): 645, 1980 (no refs).

Inbred mice of the H-2^c haplotype (CBA/J, CBA/N, AKR, C3H/HeJ, and C3H/HeN) were subjected to a single 30-min exposure to 2,450 MHz microwaves. Six days later, significant increases in the frequency of complement receptor positive (CR⁺) spleen cells as compared to sham-exposed controls were observed. No such increase was observed in mice of the H-2^c, H-2^d, and H-2^e haplotypes. F₁ mice derived from C3H/HeJ (H-2^c) responders and C57Bl/6 (H-2^d)

nonresponders reacted with increases in CR⁺ cells after irradiation. Congenic B6-H-2^c mice having the responder H-2^c haplotype and nonresponder background genes failed to respond to microwave irradiation, whereas AKR-H-2^c mice with the background genes of the AKR strain but with the H-2^c haplotype acted as responders. The results indicated that there is a genetic predisposition for microwave-induced effects on the immune system. The gene or genes controlling the microwave-induced increase in CR⁺ cells was found outside the H-2 complex with responsiveness being dominant over nonresponsiveness. The observation that in inbred mice responsiveness was associated with the H-2^c haplotype suggests that responsiveness may be controlled by non-H-2 genes closely associated with the H-2 complex.

6780 THE EFFECT OF MICROWAVES (9.7 GHz) ON MEMBRANE BOUND ACETYLCHOLINESTERASE IN THE VAGAL HEART SYSTEM (MEETING ABSTRACT). (Eng.) Young, W. (Sch. Optometry, Univ. California, Berkeley, CA 94720). *Fed Proc* 39(3, Part 1): 410, 1980 (2 refs).

The effect of microwave irradiation at 9.7 GHz on the vagal heart system was studied. Acetylcholine (ACh) was introduced either by electrical stimulation of the vagus nerve or by injection into the sinus. Microwave irradiation (30 min) at the mW/cm²-level inhibited the membrane-bound acetylcholinesterase (AChE) activity by 60%. The activity gradually returned to normal. Contractility of the cardiac muscle was not affected. The cardiac rate, however, fell to about 75% of the control. Addition of calcium in the perfusing fluid produced a similar inhibitory effect. The effect of microwave on membrane-bound AChE is interpreted as a release of bound calcium from the glycocalyx of the postjunctional membrane.

6781 LACTATE DEHYDROGENASE ACTIVITY OF HUMAN ORAL LEUKOCYTES MIGRATED BY MICROWAVE STIMULATION (MEETING ABSTRACT). (Eng.) Radchenko, V. (Res. Inst., American Dental Assoc. Health Foundation, Chicago, IL 60611). *J Dent Res* 59(A): 505, 1980 (no refs).

The stimulating effect of low energy microwaves on human oral leukocyte migration rate (OLMR) was studied. Saliva samples were collected by rinsing with 0.9% saline solution (about 10 ml) from 25 adult men before and after exposure to microwave radiation (1.0-2.0 W, continuous or pulse modulated, duration 10 min). Lactate dehydrogenase (LDH) enzyme activity of the migrated leukocytes was measured to quantify their viability. LDH activities of precipitate (intact leukocytes) and supernatant (damaged leukocytes) of saliva samples after 15 min centrifugation at 3,000 revolutions/min were assayed. The results suggest that low energy microwave radiation

stimulates human OLMR without degradation of leukocytes as indicated by their unaltered LDH activity.

6782 A STUDY OF MAGNETOPHOSPHENE THRESHOLD PARAMETERS (MEETING ABSTRACT). (Eng.) Lobel, D. (Natl. Magnet Lab., Massachusetts Inst. Technology, Cambridge, MA); Hale, J. R. *Invest Ophthalmol Vis Sci* 19(Suppl.): 8: 1980 (no refs).

A pilot study using normals and clinical subjects to investigate various parameters of magnetophosphenes was carried out. Alternating magnetic fields up to 1,000 G were generated using a coil and a variable frequency generator. Regulation of coil current and generator frequency allowed the investigation of frequency variation and root mean square field intensity on subjective thresholds. Individuals were seated facing a uniformly-illuminated hemisphere in a darkened room, with the magnetic coil adjacent to the eye to be measured. Varying the intensity and color of the light illuminating the hemisphere not only aided in measuring changing threshold levels, but enabled the investigation of the effects of various states of adaptation on the threshold. Use of the hemisphere aided in documenting the extent of the perceived phosphenes in the subject's visual field.

6783 INFLUENCE OF ELECTRIC FIELDS ON RPE GROWTH RATES (MEETING ABSTRACT) (Eng.) Byer, H. H. (Scheie Eye Inst., Philadelphia, PA 19132); Sassani, J. W. *Invest Ophthalmol Vis Sci* 19(Suppl.): 41: 1980 (no refs).

The effect of electric fields (E) on the cellular function (as measured by the proliferation rate) of bovine retinal pigment epithelial cells (RPE) was studied. Adult bovine RPE cells were grown in tissue culture while exposed to E fields at various magnitudes (1,300, 1,000, 650, and 300 V/cm) and pulse intervals (1/60, 1/30, 1/15, and 1/5 Hz), as well as with reversed field direction. Growth curves were generated by counting stained and fixed cells that were retrieved on alternate days over a 2-wk period. Results showed that the in vitro growth rates of RPE are significantly increased over controls when higher field strengths are applied in the apical-to-basilar direction, whereas growth rates are lower than controls when the field direction is reversed. While it is known that fibroblast production of deoxyribonucleic acid and collagen can be enhanced by E fields, these results appear to be the first demonstration of electric field influence on RPE.

6784 LENS CATARACT FORMATION IN VITRO: THE EFFECTS OF HEAT AND

MICROWAVE IRRADIATION (MEETING ABSTRACT). (Eng.) Stewart-DeHaan, P. J. (Univ. Western Ontario, London, Ontario, Canada); Trevithick, J. R.; Creighton, M. O.; Ross, W. M.; Larsen, L. E.; Jacobi, J. H. *Invest Ophthalmol Vis Sci* 19(Suppl.): 151: 1980 (no refs).

The effect of heat and microwave irradiation on rat lenses was investigated in vitro. Intact lenses in tissue culture medium were exposed to elevated temperatures for periods of up to 1 hr, followed by incubation at 35.5 C for 2 days. The maximum depth of degeneration, observed by scanning electron microscopy (SEM), was proportional to temperature up to 50 C. Lenses heated for 5 min were almost as damaged as those heated for 20 min at 41 C, suggesting that the initial heat shock is the critical factor in heat-induced cataract formation. The lenses, housed in a temperature-jacketed apparatus to be able to investigate separately the effects of elevated temperature and microwave radiation, were irradiated with 915 MHz microwave radiation using both high energy pulse (PU) and continuous wave (CW) of the same average power. The pulsed radiation was optimized for the production of thermal acoustic expansion. SEM was performed on lenses fixed immediately after irradiation. Controls at 39 C showed very small changes from normal lens morphologic appearance in both epithelial and fiber cells, whereas progressive damage (greater with PU than CW) occurred with increasing time of exposure. The maximum damage, observed at this temperature, occurred at the maximum PU time of exposure tested (20 min); this involved the production of holes in the equatorial lens fiber cells to a depth of approximately 80-100 μ m below the lens capsule.

6785 A NON-INVASIVE FORM OF ELECTRICAL STIMULATION OF UNUNITED FRACTURES OF THE TIBIA (MEETING ABSTRACT). (Eng.) de Haas, W. G. (No affiliation given). *J Bone Joint Surg [Br]* 62B(1): 131: 1980 (no refs).

Fourteen patients were treated with an iron-cored electromagnet for ununited fractures of the tibia. The apparatus consisted of a U-shaped laminated iron electromagnet and an electronic power unit that supplied a square wave signal at a repetition rate of 1 Hz. The magnetic flux density reached 900 G at the pole pieces. The magnetic field was orientated transversely across the fracture site for approximately 20 hr/day for 4-8 wk after which cast immobilization was continued for 4-6 mo. Fourteen of the 15 fractures united soundly. Refractures, which have subsequently healed, occurred in three patients. No harmful effects were observed.

6786 THE TREATMENT OF FRACTURE NON-UNION BY ELECTROMAGNETIC INDUC-

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TION (MEETING ABSTRACT). (Eng.) Sutcliffe, M. L. (No affiliation given); Sharrard, W. J.; MacEachern, A. G. *J Bone Joint Surg [Br]* 62B(1): 123; 1980 (no refs).

Twenty-three patients suffering from either infantile pseudarthrosis of the tibia (5 patients) or nonunion of a fracture (18 patients) were treated by pulsing electromagnetic fields. The affected bones included 10 ununited fractures of the tibia, 3 of the femur, 3 of the radius, 1 of the ulna, 1 failed arthrodesis of the ankle, and 5 infantile pseudarthroses of the tibia and fibula. The time since fracture ranged from 1 to 29 yr. Two Helmholtz-aiding "O" coils were placed on the outer surface of a plaster cast and fed by a highly specific pulsed current (Bassett's technique). A magnetic field of about 2 G induced a flow of current in the bone of 1.0 to 1.5 mV/cm². Treatment was applied for 15 hr/day until clinical and radiologic evidence of union was present. As union proceeded, axial impactive compression exercises and progressive weight-bearing in plaster were used to stimulate the progress of union. Union was achieved in 15/18 ununited fractures and 4/5 pseudarthroses of tibia, with a mean time of union of 5.5 mo and 7.75 mo, respectively. It is suggested that failure may have been due to inadequate immobilization or the presence of a synovial pseudarthrosis. The presence of metal internal fixation did not bar success, and sepsis or sinuses usually healed during treatment.

6787 THE CAUSALITY OF ELASTIC, ELECTRICAL AND MAGNETIC FORCES IN THE HEALTHY AND DEFECTIVE BONE (MEETING ABSTRACT). (Eng.) Kraus, W. (Institut für Medizinische Physik, Augustenstrasse 41, 8000 München 2, W. Germany). In: *Proceedings of the Second Meeting of the European Society of Biomechanics and First Symposium of the Groupe d'Etudes de Biomecanique Osteo-Articulaire de Strasbourg held September 13-15, 1979 in Strasbourg, France*. (General Assembly of the Council of Europe): C-1; 1979 (no refs).

A hypotheses concerning the interaction of mechanical and magnetic forces in the living structure, analogous to the mechanical-electrical causality of piezoelectrical polarization of collagen fibers, is presented. It is proposed that separation of charges in the cytoplasm and the build up of electrical potential on either side of the mitochondrial membrane are produced by magnetic forces. The conditions of the Hall effect are met in the healthy organism. This arises in the presence of the earth's magnetic field via acceleration of ions during the elastic waves of systolic blood pulsation in the vessels. The decrease in the amplitude of elastic oscillation (e.g., because of arteriosclerosis) would thus lead to a decrease in the charge separation and the electrical membrane potential. The proposed therapy suggests that Maxwell induction of oscillating magnetic fields can compensate for the resulting mechanical deficit. The

results of some experimental applications of electrodynamic field therapy are also reported. 1) Experiments with probes of human spongy bone resected during hip joint operations were conducted using electrodynamic field therapy. The probes were then further stimulated in Hank's solution, saturated with calcium phosphate, and within 24 hr showed a highly significant increase in calcium uptake (approximately 70% higher than nontreated probes). X-ray analysis showed a significant increase in density of the stimulated probe. 2) Experiments with screw and plate implantations in the lower jaws of beagles demonstrated that the electrodynamic procedure resulted in bone that was superior to the control group on the basis of mechanical strength and on histologic analysis (ratio 1:3, $p=0.0001$). 3) Preliminary results on 132 patients receiving magnetic field treatment for advanced loosening of prostheses demonstrated that a revisionary operation was no longer deemed necessary in 92 patients. The average duration of treatment was for 20 wk, 40 min 2-3 times/day. The period of observation extended over 5 yr.

6788 RECENT EXPERIMENTAL AND CLINICAL RESULTS OF THE ELECTRODYNAMIC FIELD THERAPY (KRAUS-LECHNER) (MEETING ABSTRACT). (Eng.) Lechner, F. (Dept. Surgery, Garmisch-Partenkirchen Hosp., Garmisch-Partenkirchen, W. Germany); Ascherl, R. In: *Proceedings of the Second Meeting of the European Society of Biomechanics and First Symposium of the Groupe d'Etudes de Biomecanique Osteo-Articulaire de Strasbourg held September 13-15, 1979 in Strasbourg, France*. (General Assembly of the Council of Europe): C-2; 1979 (no refs).

Electrodynamic field therapy (EFT), a semi-invasive procedure for electrostimulation of bone repair using low-frequency alternating current, has been used in clinical practice for 9 yr. EFT results in an external magnetic field of 2.4×10^{-1} A/mm and a current density of approximately 10 μ amps/mm² near the electrode's surface. Results from recent experiments with EFT are briefly described. 1) When calcium uptake was measured in vitro after EFT, a significant increase (3.84 compared to 2.2 μ vals/cm² for controls) was demonstrated in two spongy bone blocks prepared from the resection end of the femoral neck after total replacement of the hip joint. 2) Bone consolidation was achieved in 92% of 273 patients suffering from pseudoarthroses; hospitalization usually required only about 8 wk. 3) EFT used to treat some cases of primary or secondary bone tumors, when radiation, cytostatics, and amputation had been refused, demonstrated a transformation of osteoclastic reactions to osteoblastic reactions.

6789 BONE GROWTH STIMULATION--CRITIQUE AND ONE POINT (MEETING ABSTRACT). (Eng.) Steinemann, S. G. (Institut

Straumann, Waldenburg, Switzerland). In: *Proceedings of the Second Meeting of the European Society of Biomechanics and First Symposium of the Groupe d'Etudes de Biomecanique Oste-Articulaire de Strasbourg held September 13-15, 1979 in Strasbourg, France*. (General Assembly of the Council of Europe): C-3: 1979 (3 refs).

Three physicochemical effects are discussed in relation to the proposed electric and magnetic mechanisms for bone growth stimulation. 1) According to Neumann's principle, excitation by magnetic and electric fields or current cannot produce the high differentiation of the solid bone matrix; at best, only a diffuse precipitation of the solid matter is possible. 2) The response of a material (i.e., tissue) to electromagnetic stimulation is completely determined by material equations. The energies of polarization may then be obtained and compared with chemical and mechanical free energies. This energy, however, is too small to account for the suggested stimulation procedures. 3) The possible stimulation by current electrodes may be explained by Faraday electrode reactions. A transport equation must also be solved to obtain local ion concentrations around the electrode. Thus, the effect of a direct current stimulation could be explained simply by "local alkalosis" at the cathode, which results in local storage of calcium and phosphate, and "local acidosis" at the anode, which mobilizes the calcium from storage. Thus, if the buffer capacity of the extracellular fluid is overwhelmed, a current threshold should be observed. High currents should, on the other hand, induce toxicity so that a "stimulation window" becomes apparent. It is concluded that with one exception, the laws of physics do not support bone growth stimulation by electromagnetic fields.

6790 THE RESPONSE OF BIOLOGICAL SYSTEMS TO ELECTRIC CURRENTS INDUCED BY PULSED MAGNETIC FIELDS (MEETING ABSTRACT). (Eng.) Jackson, S. F. (Strangeways Res. Lab., Cambridge, England); Farndale, R. W.; Jones, D. In: *Proceedings of the Second Meeting of the European Society of Biomechanics and First Symposium of the Groupe d'Etudes de Biomecanique Oste-Articulaire de Strasbourg held September 13-15, 1979 in Strasbourg, France*. (General Assembly of the Council of Europe): C-4: 1979 (8 refs).

Studies to determine the way biologic mechanisms respond to induced electric currents have been conducted at the Strangeways Laboratory in Cambridge, England to determine 1) if the normal rates of synthesis of major extracellular macromolecules are altered during the laying down of osteogenic and chondrogenic tissues; 2) if the cellular mechanisms under the control of cyclic-3',5'-adenosine monophosphate are also affected; 3) if the mineralization processes are enhanced, and if so, how; and 4) how specific ion transport across the cellular membranes is modulated. Organ cultures of

long bone rudiments exposed to treatment with magnetic fields, consisting of 8 days of alternating 6-hr on-off periods, were used as models. The results indicated that considerable welts of periosteal bone are laid down during the second half of culture, that the dry weight of the bony shafts is increased by over 50%, that the net rates of synthesis of hydroxyproline and hexosamine (used, respectively, as a measure of the amount of collagen and ground substance produced) are not grossly accelerated by treatment with the coils, and that the rate of uptake of bound ⁴⁵Ca osteogenic tissue, expressed as counts/min/μg deoxyribonucleic acid, may be critically inter-related with the phased (6 hr) on-off periods of treatment. To determine if specific ion transport across the cellular membranes is modulated, the ion flux of various cell systems exposed to pulsed magnetic fields (PMF) was measured, and specific inhibitors were used to determine if the observed ionic movements across the cell membrane were mediated by the metabolic activity of the cell or by a direct effect on the ion. The potassium flux in the human red blood cells was studied with a ⁸⁶Rubidium tracer. The results indicated that the flux rates of both ouabain-sensitive and ouabain-insensitive components are altered as compared to those of untreated controls.

6791 ELECTROMAGNETIC MODULATION OF FRACTURE REPAIR IN THE RAT (MEETING ABSTRACT). (Eng.) Christel, P. (Bioelectrochemistry Lab., Orthopedic Res., Dept. Orthopedic Surgery, Columbia Univ., 630 West 168th St., New York, NY 10032); Cerf, G.; Pilla, A. A. In: *Proceedings of the Second Meeting of the European Society of Biomechanics and First Symposium of the Groupe d'Etudes de Biomecanique Oste-Articulaire de Strasbourg held September 13-15, 1979 in Strasbourg, France*. (General Assembly of the Council of Europe): C-7: 1979 (no refs).

The hypothesis that a kinetic perturbation of the real-time electrical response of a cell and/or tissue system may have a modulating effect on specific cellular functions was assessed. Utilization of the electrochemical information transfer approach coupled with ancillary real-time transient analysis of living cell membranes resulted in the configuration of a family of low-level pulsating current waveforms predicted to have a biologic effect. The waveform configurations are inductively coupled and are designed to examine several perturbation/relaxation regimens that have quantitatively different real-time coupling to the cell or tissue system. In addition, the effect of time and amplitude asymmetry in these necessarily bipolar signals was assessed. The specific waveforms surveyed consisted of single pulses of 325-μsec duration having repetition rates of 70-500 Hz and of pulse bursts of 200-μsec duration having burst durations of 5-50 msec and burst repetition rates of 2-20 Hz. For each general waveform type a preliminary assessment of the variation of induced tissue current density (per pulse) from 0.2 to 2

$\mu\text{A}/\text{cm}^2$ was carried out. A transverse mid-shaft radial osteotomy was performed bilaterally on Sprague-Dawley rats (body wt 250-300 g); after recovery, each animal was exposed for 12 hr/day to each waveform tested and then sacrificed 14 days postoperatively. Each properly aligned radius (average 11 samples for each of the 15 waveforms) was subjected to a destructive tensile test. The results show that the induced waveform configuration as well as the perturbation/relaxation modality had a statistically significant effect on ultimate tensile strength, stiffness, brittleness, and energy to failure. The effect of time/amplitude asymmetry for each waveform type showed that a more advanced healing stage is achieved when the opposite polarity portion of the waveform is sufficiently short to enable a kinetically unipolar real-time tissue coupling to be achieved. For example, a 325- μsec single pulse having a 20- μsec opposite polarity duration resulted in a 20% increase in ultimate tensile strength, whereas the same pulse with a 4-msec low amplitude opposite polarity duration, resulted in a statistically significant difference in this quantity. Similar effects were obtained as a function of the signal repetition rate. The "best" signal tested resulted in a 30% increase in ultimate tensile strength versus controls. This preliminary study shows that electromagnetically-induced electrochemical information transfer may be a valuable tool for the study of fundamental cellular processes. The effect of the mode of the kinetic coupling (perturbation/relaxation regime) on the ultimate tissue result may provide evidence concerning the effect of the cell's microenvironment, its cycle stage, state of differentiation, etc., on the required waveform parameters for optimal kinetic modulation.

6792 ELECTROCHEMICAL INFORMATION TRANSFER VIA PULSING ELECTROMAGNETIC FIELDS (MEETING ABSTRACT). (Eng.) Pilla, A. A. (Biochemistry Lab., Orthopedic Res., Dept. Orthopedic Surgery, Columbia Univ., 630 West 168th St., New York, NY 10032). In: *Proceedings of the Second Meeting of the European Society of Biomechanics and First Symposium of the Groupe d'Etudes de Biomecanique Osteo-Articulaire de Strasbourg held September 13-15, 1979 in Strasbourg, France.* (General Assembly of the Council of Europe): C-8, 1979 (no refs).

A theoretical model that provides real-time electrochemical response pathways for a cellular system that has been exposed to low level current is proposed. The interactions and/or transport of charged species at a cell's surfaces and junctions can exhibit kinetic potential dependence that is relatively reversible. Basically three general types of electrochemical processes are considered. The first involves the dielectric nature of the cell membrane coupled with nonspecific electrostatic interactions at the membrane/fluid interfaces. The second and third processes involve specific binding and membrane and aqueous transport and their intercoupling. The

results of electrochemical kinetic analysis indicate that excitation of membrane transport, i.e., ionic membrane flux, appears to be the predominant real-time response modality. Thus, the choice of waveform parameters involves consideration of the expected exponential dependence of amplitude (current density) versus repetition rate. In addition, the ability of a given cell to respond via a regulatory (versus, e.g., defense) pathway will probably depend on the net rate of change of intracellular ionic concentration versus the kinetics of the regulatory process involved. A family of current waveforms has been developed to couple with expected ranges of cell surface coupled regulatory kinetics. This approach was tested on several in vitro and in vivo systems. The rate of amphibian red blood cell (RBC) "dedifferentiation" was shown to be a window function of the repetition rate of bipolar single pulse waveforms in which the duration of both polarities was sufficient to kinetically couple with, e.g., membrane transport. The rate of Ca^{++} uptake by embryonic chick limb rudiments at short times (1 hr) was found to be significantly larger for long than for short perturbation times, with all other parameters equal. In another experiment, the enhancement of deoxyribonucleic acid synthesis in isolated bone cells was dependent on the time/amplitude asymmetry of induced bipolar waveforms, demonstrating effects similar to those observed with the amphibian RBC system. The results of these experiments and other more recent studies demonstrate that the particular cell response to which induced pulsating current waveforms can couple depends on the cell and its microenvironment.

6793 NON-INVASIVE OUT PATIENT TREATMENT OF SURGICALLY-RESISTANT NON-UNIONS BY INDUCED PULSING CURRENT: CLINICAL RESULTS (MEETING ABSTRACT). (Eng.) Mulier, J. C. (Dept. Orthopedic Surgery, Univ Leuven, Leuven, Belgium); Spaas, F. In *Proceedings of the Second Meeting of The European Society of Biomechanics and First Symposium of the Groupe d'Etudes de Biomecanique de Osteo-Articulaire de Strasbourg held September 13-15, 1979 in Strasbourg, France.* (General Assembly of the Council of Europe): C-9, 1979 (no refs).

The results of a clinical study that involved the application of electromagnetic coils externally over fracture sites to treat nonunions are reported. Twenty-one patients with long-standing nonunions (6 with infections), who had previous unsuccessful surgical intervention (average, 3.1 interventions/person) at least 50 mo before treatment (range, 5 mo-4.5 yr), were treated. The fractures were of the tibia in 17, humerus in 3, and ulna in 1. The prior disability time ranged from 1.25 to 8.33 yr. The coils and pulse generator were adapted to the patient on the basis of the site's dimensions, location, and type of fracture, and were used for 12-16 hr/day. The patient feels nothing, and a temperature rise of only about

0.001 C occurs. Nonweight-bearing is essential during the initial months of treatment. At the time of this report, treatment resulted in nine patients with total fractures to a definable end-point, six with functional union (bridging on x-ray; no mobility, pain, or tenderness; free or supported weight-bearing), two withdrawals from the study, and one without any progress. Problems associated with the routine included the need for absolute accuracy in locating the coils (by means of x-rays), application of the correct electrical signals, and occasional lack of patient cooperation. The results demonstrate that the treatment was effective in some cases of difficult non-unions. The authors conclude that the technique is generally well accepted and economically of interest since it avoids costly surgery and hospitalization in the future.

6794 FRACTURE HEALING AND ELECTRICAL STIMULATION (MEETING ABSTRACT). (Eng.) Perren, S. M. (Lab. Experimental Surgery, Swiss Res. Inst., CH-7270 Davos-Platz, Switzerland); Chapman, M. W. In: *Proceedings of the Second Meeting of the European Society of Biomechanics and First Symposium of the Groupe d'Etudes de Biomecanique de Osteo-Articulaire de Strasbourg held September 13-15, 1979 in Strasbourg, France*. (General Assembly of the Council of Europe): C-10; 1979 (no refs).

The mechanism of action of electrical bone stimulation and the theoretical basis for the various techniques are discussed. Direct current produces bone formation mostly at the cathode. It has not yet been determined if this is a specific biologic reaction. The bone formation that is observed may be a reaction to electrical irritation, with electrical information serving as the link between mechanical load and functional adaptation in the bone. Alternating potential arising out of changing bone stresses has not yet been demonstrated to produce meaningful changes in the bone structure; therefore, the authors conclude that piezoelectricity cannot account for the mechanism of electrical stimulation. Three different types of electrical stimulation based on different theoretical explanations are currently in use: 1) direct current applied at 10-20 μ amp via metal electrodes implanted in bone (Brighton), 2) electromagnetic stimulation applied as a pulsating magnetic field transverse to the longitudinal axis of bone (Bassett), and 3) the combined method of Kraus and Lechner that produces a magnetic field parallel to the longitudinal axis of bone, and, via an implanted inductor, generates alternating potentials of approximately 100 mV. The minimum requirements for proof of the efficacy of these methods are experimental verification in a double-blind study conducted in an independent laboratory, quantitatively significant results using an adequate experimental model, and a controlled clinical study. Pseudoarthroses are one possible complication of fracture healing. In practice, hypertrophic pseudoarthroses pose the major clinical

problem since they are frequently complicated by infection. It is suggested that any method that can provide equal or better results than cancellous bone grafting or can be used to augment the healing from bone grafting is of interest. The authors conclude that the stimulation of bone healing is an area of potential fruitful laboratory research, in view of its important clinical applications. Most likely the ideal solution to the stimulation of bone healing will be a combination of several differing methods that permit achievement of an optimal functional result.

6795 RADIOFREQUENCY LESIONS IN THE TREATMENT OF PAINFUL SYNDROMES: CONSIDERATION IN 155 CASES (MEETING ABSTRACT). (Eng.) Frank, F. (Second Neurosurgical Div., Ospedale Maggiore Sezione Bellaria, Bologna, Italy); Galassi, E.; Frank, G.; Gaist, G.; Tognetti, F. *Acta Neurochir (Wien)* 51(1/2): 144; 1979 (no refs).

Percutaneous radio frequency techniques were used over a 15-mo period to treat painful syndromes. One hundred and eighteen trigeminal thermorhizotomies and 37 cervical cordotomies were performed with this procedure. Special references to the indications, advantages, and limits of this kind of management are presented.

6796 EFFECT OF ELECTRIC FIELDS ON BONE ATROPHY OF DISUSE IN THE RAT (MEETING ABSTRACT). (Eng.) Perumal, T. A. (Dept. Physiology, Christian Medical Coll., Vellore, India); Bullard, T. K.; Jayachandran, C. *Indian J Physiol Pharmacol* 22(2): 227-228; 1978 (no refs).

The effect of capacitively coupled electric fields on the development of disuse atrophy in bone was studied in the rat. One hind limb of a rat was immobilized in a plaster cast containing two insulated brass plate electrodes that were located on the lateral and medial surfaces of the limb. Electric pulses of 1-msec duration (100 V and 200 V, 500 Hz) were applied to the electrodes producing an electric field around the limb between them for a period of 6 hr/day. The contralateral limb was free and not restricted in any way. A dose of tetracycline (100 mg/g) was given intraperitoneally on the 1st and 14th day of the experiment. Control animals were subjected to the same procedures without application of the electric fields. At the end of 21 days of treatment all animals were sacrificed and the following parameters were measured in tibia of both limbs: dry wt, percent ash, new bone deposition rate, and x-ray density. Differences obtained between electrically treated and normal bones in experimental animals were compared with differences observed between "sham-treated" and normal bones in control animals. The results indicated that while bone atrophy of disuse was produced to some extent in both experimental and control animals, the electric

fields used were effective in decreasing the degree of bone atrophy of disuse caused by immobilization.

6797 BONE HEALING UNDER ALTERNATING ELECTROMAGNETIC FIELDS? (MEETING ABSTRACT). (Eng/Ger.) Sturmer, K. M. (Abteilung fur Unfallchirurgie, Universitätsklinikum, D-4300 Essen, W. Germany); Kehr, H.; Schmit-Neuerburg, K. P.; Seidel, K. *Langenbecks Arch Chir* (47): 709-710; 1978 (no refs).

Atrophic and infected nonunions of both ulnae in 21 female beagle dogs were treated with alternating electromagnetic fields and alternating current transducers at the bone, according to the Kraus' technique, in a right-left trial. X-rays, microangiography, microradiography, polychrome sequence labeling, stained histology, and polarization were evaluated. One group showed more periosteal reaction on the treated side but not better healing. The second group with additional cancellous bone graft developed more new bone in the defect on the electrically treated side compared with the control side.

6798 NEUROBEHAVIORAL CONSEQUENCES OF MICROWAVE IRRADIATION IN JAPANESE QUAIL (*COTURNIX COTURNIX JAPONICA*) EXPOSED DURING EMBRYOGENESIS (MEETING ABSTRACT). (Eng.) Cabe, P. A. (Lab. Behavioral and Neurological Toxicology, Natl. Inst. Environmental Res. Sciences, Research Triangle Park, NC 27709); Burne, T. A.; McRee, D. I. *Environ Health Perspect* 33: 322; 1979 (no refs).

Eight male Japanese quail exposed to 2.450 MHz microwave irradiation at an incident power density of 5 mW/cm² over the first 12 days of incubation were tested in a series of behavioral screening procedures. Eight male birds served as controls. Body weights, which did not differ between exposed and control groups at any time, were measured weekly from 7-18 wk. Four triweekly evaluations of spontaneous motor activity also showed no microwave effect. Exposed birds, however, did show significantly fewer avoidance responses in a shock-motivated escape-avoidance test, both during acquisition training and in a 3-wk retention test. Control birds had significantly more intertrial interval response, and significantly fewer escapes than exposed animals on retention testing. Failures to respond (escapes lost) were not different at either acquisition or retention. A series of operant conditioning procedures using a food rewarded key-peck response demonstrated that exposed birds had a somewhat higher operant level (more likely to spontaneously peck the key, $0.06 < p < 0.07$), but both groups acquired the response equally well under an autoshaping procedure. Exposed birds, however, emitted responses at a con-

sistently lower rate under a random interval schedule of reinforcement. These results indicate the feasibility of the several screening techniques used, the potential usefulness of the Japanese quail model, and the possible behavioral teratogenic effects of microwave irradiation.

6799 EFFECTS OF MICROWAVE RADIATION ON THE VITALITY OF ISOLATED FROG SCIATIC NERVES (MEETING ABSTRACT). (Eng.) McRee, D. I. (Lab. Environmental Biophysics, Natl. Inst. Environmental Health Sciences, Research Triangle Park, NC 27709); Wachtel, H. *Environ Health Perspect* 33: 342; 1979 (no refs).

Isolated frog sciatic nerves were exposed in a waveguide system to 2.45 GHz continuous wave (CW) microwave radiation at specific absorption rates (SARs) ranging from 0 mW/g to 100 mW/g. The effect of microwaves on the vitality of the nerves was measured in terms of the ability of the nerves to sustain a high firing rate over prolonged periods without suffering appreciable changes in the characteristics of the compound action potential (CAP). The nerves were stimulated by using twin pulses separated by a 5-msec interval at a repetition rate of 50 pulses/sec. For SARs >10 mW/g, the exposed nerves were first seen to undergo a prolongation of their refractory period, followed later by severe decreases in the maximal CAP. These effects appeared to be microwave-specific; they were not observed either when the temperature was held constant or when the temperature was increased in the absence of microwaves. The effects also were found to be irreversible since the nerves did not revitalize or increase their activity on termination of exposure. No significant effects on vitality of the nerves were observed for a SAR of 5 mW/g.

6800 EXPOSURE OF PREGNANT MICE TO 2.45 GHz MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) McRee, D. I. (Lab. Environmental Biophysics, Natl. Inst. Environmental Health Sciences, Research Triangle Park, NC 27709); Nawrot, P. *Environ Health Perspect* 33: 342, 1979 (no refs).

The effects of 2.45 GHz microwave radiation on pregnant mice (CD-1 strain, 49- to 55-days old, 27-29 g) and their developing fetuses were studied. Separate groups of mice were exposed to 5, 21, and 30 mW/cm² incident power density. The corresponding specific absorption rates were approximately 5.3, 22.3, and 31.8 mW/g. The mice were exposed for 8 hr/day, 4 hr in the morning, 1 hr back in the cages for feeding, and 4 hr additional exposure in the afternoon. The 5-mW/cm² exposure group was exposed from day 1 to day 15 of pregnancy. Separate groups of animals were exposed from days 1 to 6 and days 6

to 15 for power densities of 21 and 30 mW/cm². Control groups were established to evaluate the effects of other factors, such as elevated temperature and handling. Environmental temperatures were set to simulate the thermal stress produced by microwave exposure. Maternal and fetal response to the different conditions was determined by measuring pregnancy rate, maternal weight gain, number of litters, implantation sites per litter, resorptions, live fetuses per litter, average fetal weight, stunted fetuses, dead fetuses, and malformed fetuses. The results of the experiment show that a significant decrease in pregnancy rate from 86 to 72% was measured due to handling during the early stages of pregnancy (days 1-6). An additional decrease to 65% occurred at exposure to 21 mW/cm² (days 1-6), and to 50% at 30 mW/cm² (days 1-6). A significant decrease in maternal weight gain was measured in all handled groups of animals. No difference was measured between the irradiated handled and temperature handled groups. A significant difference in average fetal weight was measured due to a combination of handling and heating. No significant difference occurred between irradiated handled and temperature handled groups. A significant increase in congenital malformations occurred only at the 30 mW/cm² (6-15 days) exposure. An increase from 1.7% in the temperature handled control group to 3.1% in the irradiated handled group was measured. Two-thirds of the malformations were cleft palate.

6801 **EFFECT OF 2,450 MHz MICROWAVE RADIATION ON RAT PERITONEAL CELLS (MEETING ABSTRACT).** (Eng) Ortner, M. J. (Lab. Environmental Biophysics, Natl. Inst. Environmental Health Sciences, Research Triangle Park, NC 27709); Galvin, M.; Turek, N.; Hall, C. *Environ Health Perspect* 33: 343; 1979 (no refs).

A microwave exposure system was developed for studying functioning secretory cells under the influence of nonionizing radiation. Cells were exposed to 2.450 MHz microwave radiation at both 8.5 and 42.5 mW/ml of cell suspension for periods of up to 3 hr. The cells were maintained at 37°C throughout the exposure period. The specific absorption rate of Locke's solution containing mast cells was determined directly from the time-temperature profile of specimens at the beginning of exposure. Microwave exposure caused no change in the morphologic characteristics or cell viability as determined by trypan blue exclusion. When irradiated mast cells were stimulated with compound 48/80, the dose/response curves showed that, even at submaximal concentrations, prior irradiation of mast cells did not affect 48/80-induced secretion. When mast cells that had been continuously irradiated for 3 hr were treated with 48/80 during irradiation, the secretory response to 48/80 was not inhibited. These experiments suggest that noncytotoxic membrane fusion and active secretion are unaffected by 2.450 MHz microwave radiation. Mast cells heated to 45°C

for 10 min became totally refractory to 48/80, whereas cells from the same sample exposed to 3 hr of radiation at 37°C responded normally, indicating that no heat-induced damage to the mast cell membranes during microwave exposure was observed. It is suggested that rat peritoneal mast cells can be useful as a biologic test system to determine the effects of microwave exposure on isolated cells.

6802 **ELECTROMAGNETIC RODENT CONTROL FOR POULTRY FACILITIES (MEETING ABSTRACT).** (Eng) Muller, H. D. (Cooperative Extension Service, Univ. Georgia, Athens, GA 30602). *Poult Sci* 57(4): 1107; 1978 (no refs).

The role of electromagnetic devices for rodent control in poultry facilities is reviewed. Field evaluations of several commercial electromagnetic rodent control devices have demonstrated rodent population reduction when units were properly located and installed. Rodent control programs utilizing magnetic repellers have been assisted by harborage reduction. Initially, devices evoked increased activity such as burrowing followed by atypical behavior including distorted diet patterns, burrow avoidance, lethargy, reduced reproduction, anorexia, and hypoactivity resulting in death. The mode of action is hypothesized to involve an induced neurologic dysfunction manifested by reduced reaction time and asthenia. Recovery was noted when the magnetic field was interrupted or withdrawn. Responses were confined to rats and mice. Rodent control devices that reputedly evoke rodent control by electromagnetic charging of the ground and/or structures offer a new approach to rodent damage and hazard control.

6803 **EXPOSURE OF CHICKEN EGGS TO AN ELECTROMAGNETIC FIELD PRIOR TO INCUBATION (MEETING ABSTRACT).** (Eng) Hester, P. Y. (Dept. Animal Sciences, Purdue Univ., West Lafayette, IN 47907); Fabijanska, I. *Poult Sci* 57(4): 1145; 1978 (1 ref).

White Leghorn eggs were exposed to electromagnetic (EMG) fields prior to incubation. The eggs were individually rolled through a magnetic coil with an exposure time of 3 sec/egg. Hatchability percent and body weights of chicks from control and treated eggs were determined at 20.5 and 21.5 days of incubation. The treated eggs of trial 1 were exposed to a 90 G EMG field produced by a direct current. The four treated groups of trial 2 consisted of the following: direct current 125 G, direct current 160 G, alternating current 125 G, and alternating current 160 G. It was concluded that the levels of EMG energy utilized in these trials had no effect on hatchability percent, body weight means, or hatching time. These results were in contrast to previous United States patent

description, which claimed that comparable levels of EMG energy caused a 5-8% increase in hatchability percent when compared with untreated controls.

6804 EFFECTS OF MICROWAVES ON FEATHER RELEASE IN CHICKENS (MEETING ABSTRACT). (Eng.) Kula, S. A. (Dept. Animal Sciences, Colorado State Univ., Fort Collins, CO 80523); Miller, B. F.; Enos, H. L.; Goble, J. W. *Poult Sci* 57(4): 1150; 1978 (no refs).

One hundred and ninety-three birds were processed by microwaves. All of the feather tracts were tested for feather release and tissue damage on each bird. A statistical discriminant analysis was done and it was concluded that proper feather release can be achieved, depending on the bird's weight, the power used, and the time stressed, and also depending on which area of the bird the feather release is observed (either extremities or torso feather tracts). An estimation of energy consumption indicated hot water scalding would require about 200 BTU per bird, compared to 132 BTU using microwave-induced feather release, a potential energy savings of 34%.

6805 REPRODUCTION IN JAPANESE QUAIL SUBJECTED TO MICROWAVE RADIATION AS EMBRYOS (MEETING ABSTRACT). (Eng.) Thaxton, J. P. (Dept. Poultry Science, North Carolina State Univ., Raleigh, NC 27650); Parkhurst, C. R.; McRee, D. I. *Poult Sci* 57(4): 1167; 1978 (no refs).

Japanese quail embryos were subjected to microwave radiation exposure during the first 12 days of embryogenesis. Nonexposed quail eggs served as controls. Reproductive performance was monitored from 6 through 22 wk of age. Nonexposed controls of both sexes, as well as exposed females, performed normally. The exposed males demonstrated reduced sperm numbers, reduced sperm motility, and a decreased percent of fertile eggs produced by control or exposed females when paired with exposed males. Mating behavior was normal in both exposed and nonexposed males.

6806 REARING OF CHICKEN FROM HATCHING TO THE END OF THE 1ST LAYING-PERIOD IN AN ELECTRIC FIELD (30 kV/m, 50 Hz) (MEETING ABSTRACT). (Eng.) Bootz, A. (Dept. Veterinary Physiology, Free Univ. Berlin, Koserstrasse 20, D-1000 Berlin 33, W. Germany); Wittke, G.; Bayer, A.; Brinkmann, J. *Pfluegers Arch* 377(Suppl.): R55; 1978 (1 ref).

Chickens that were bred under a 5.0 kV/m electric field were continuously exposed to an alternating electric field (50 Hz) of 30 kV/m for 43 wk. The increase of weight until the 20th wk was identical with that of controls. From the 21st-43rd wk, there was no difference in egg numbers (exposed animals, 116 eggs/hen; controls, 117 eggs/hen). The mean weights of eggs, however, revealed increasing differences between animals within and outside the field. From the 26th-43rd wk, the mean egg weight of the control group increased by 11.9 g while that of the field group increased by only 5.6 g. Exposed cocks exhibited behavioral alterations, e.g., being much more aggressive than unexposed chickens. Females also showed behavioral changes, such as nesting and sitting on eggs, that were not observed in the zero-field. The eggs of the exposed and control groups were gathered and subsequently incubated. Hatching rates of about 80% resulted in both the test and control groups. All descendants of the field animals developed normally. When the laying-hens and the cocks were dissected and the organ weights determined and blood samples serologically analyzed, no anomalies were noted in the exposed animals.

6807 EFFECTS OF APPLIED MAGNETIC FIELDS ON HOMING PIGEON ORIENTATION (MEETING ABSTRACT). (Eng.) Visalberghi, E. (Istituto di Biologia Generale, Universita di Pisa, Pisa, Italy); Alleva, A. *Monit Zool Ital* 12(1): 73-74; 1978 (1 ref)

Three pigeon groups equipped with either Hemholtz coils of the Nup or Sup type or with Hemholtz coils without circulating current (controls) were released under overcast conditions from three sites (32 km ENE, 23.5 km E, and 44.5 km ESE). Thirty-three Nup, 34 Sup, and 17 control birds were tossed and 18, 17, and 10, respectively, vanishing points were recorded. Pooling the bearings resulted in findings similar to those observed in a previous study: for the Nup birds there was a significant clustering of vanishing points around the direction opposite to that of the loft ($p<0.005$), whereas for the Sup and control birds there was a significant clustering around the home direction ($p<0.05$, $p<0.05$). No significant differences were noticed in both homing and vanishing times of the different treatments. Pooled data of five releases performed under sunny conditions from three different sites (48.3 km ESE, 46.2 km SSE, and 105 km ESE) from the loft (44 Nup, 44 Sup, and 44 controls released and 27, 38, and 41 vanishing points, respectively, were recorded) showed a significant clustering of vanishing points of the three groups around the home direction (Nup $p<0.0001$, Sup $p<0.0001$, and controls $p<0.0001$). Although the mean vectors of the three distributions pointed very near the home location, a significant difference ($p<0.05$) between Sup and control distributions was observed.

Both Nup and Sup groups homed significantly slower than control birds ($p<0.009$ and $p<0.005$, respectively). No differences in the vanishing times among the three treatments were observed. Our results confirm the existence of a magnetic compass in the homing pigeon. The authors suggest that the delay in homing of Nup and Sup birds under sunny conditions be investigated.

6808 DIELECTRIC PERTURBATION OF HYDROGEN-BONDED SYSTEMS BY HIGH ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Hellemans, L. (Dept. Chemistry, Univ. Leuven, 200 D Celestijnlaan, B-3030 Heverlee, Belgium); De Maeyer, M.; Ooms, R. *Arch Int Physiol Biochim* 87(5): 1209; 1979 (3 refs).

The effect of high electric fields on chemical equilibria involving hydrogen bonding in nonpolar medium was investigated. A condition for perturbation by the field was the different polarity of the reaction partners. The nonlinear dielectric response of the perturbed systems was measured in the frequency domain of 1-100 MHz. Systems including the association of ϵ -caprolactam in cyclohexane, the association of *n*-butanol in paraffin, and the complexation with proton transfer of 2,4,6-trichlorophenol and triethylamine in cyclohexane were analyzed. The reactions were all extremely fast (nearly diffusion-controlled) and a variety of nonlinear effects of different origin was encountered. Amplitudes provided thermodynamic information (K , μ), which matched the kinetic results obtained from the relaxation times. The helix-coil equilibrium in polypeptides is established by competition between internal hydrogen bonding and bonding to solvent molecules. Measurements on some synthetic polypeptides are discussed. Interference from nonlinear effects not related to the field-promoted conformational change was illustrated. The systems stand as model for field-dependent membrane processes as conditions of polarity and field strength (100 kV/cm) were comparable in both situations.

6809 MICROWAVE MEASUREMENTS OF CRYOPROTECTANT PROPERTIES (MEETING ABSTRACT). (Eng.) Ketterer, F. D. (Harrison Dept. Surgical Res., Univ. Pennsylvania, Philadelphia, PA 19104), Macklis, J. D., Noorchashm, M. R.; Holst, H. I., Lehr, H. B. *Cryobiology* 15(6): 722, 1978 (no refs).

The nature of microwave measurement of cryoprotectant properties is briefly reviewed, and some experimental results are briefly discussed. To obtain a better understanding of the heating process, knowledge of the tissue properties is essential. The heart of the microwave measurement system is a re-entrant cavity, which allows precise determination of the single resonance frequency and bandwidth before and after the sample is inserted. From an ex-

act analytical model of the re-entrant cavity, the dielectric constant and conductivity may be determined. The cavity is then cooled and measurements are repeated, so that the electrical properties may be determined over the range of -100 to +25 C. To date the properties of pure dimethylsulfoxide, glycerol, and ethylene glycol have been measured, as well as ethylene glycol in varying concentrations. The results indicate that the electrical properties depend strongly on temperature, concentration, and choice of cryoprotectant.

6810 MICROTHERMOMETER FOR ORGAN THAWING (MEETING ABSTRACT). (Eng.) Ketterer, F. D. (Harrison Dept. Surgical Res., Univ. Pennsylvania, Philadelphia, PA 19104), Holst, H. I., Lehr, H. B. *Cryobiology* 15(6): 722-723, 1978 (no refs).

A microthermometer that is based on the minute displacement of a low-temperature liquid as temperature changes was developed. A pulsed-light-emitting diode transmits light through optical fibers to the sensor that reflects a portion back through a second bundle of fibers to a photodiode detector. The signal is processed and displayed as a digital read-out. Preliminary data on a prototype indicate a temperature range -60 to +25 C with acceptable linearity. A probe diameter of approximately 2 mm should allow the probe to be implanted in the organ prior to freeze-thawing to monitor interior organ temperatures during microwave heating.

6811 MICROWAVE EFFECTS ON VIABILITY AND HEREDITY OF MAMMALIAN CELL LINES (MEETING ABSTRACT). (Eng.) Gillois, M. (Laboratoire de Genetique Cellulaire, Centre de Recherches de Toulouse, B.P. No 12, 31320 Castanet-Tolosan, France), Auge, C., Chevret, C. In *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France* p 4, 1980 (no refs).

A method is described that permits the observation of the nonthermal effects of nonionizing electromagnetic waves (2.450 MHz) on mammalian cells. Cells were exposed to the waves in their culture medium, with their usual support. Somatic cell genetic techniques were used. Nonionizing electromagnetic waves were demonstrated to have a specific nonthermal lethal effect, to have no mutagenic effect, and to increase the mutagenic power of ethyl methane sulfonate for two established cell lines, CHO and PK 15.

6812 FREQUENCY FINE-TUNING STUDIES OF MICROWAVE INFLUENCED YEAST GROWTH (MEETING ABSTRACT). (Eng.) Grundler, W. (Gesellschaft für Strahlen- und Umweltforschung mbH, 8042 Neuherberg, W. Germany), Keilmann, F.

In: Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France. p. 4; 1980 (no refs).

Previously reported findings of frequency-dependent microwave effects on the growth rate of yeast cells are confirmed. Using an improved set-up, fine-tuning studies in a 50-MHz wide band near 41.8 GHz were conducted. The growth rates measured without irradiation were scattered by not more than $\pm 3\%$ from a mean value, while the relative growth rates of the irradiated samples deviated from 19% to -12% , depending on the frequency (on a MHz-scale). Correlation with the applied microwave power was discussed.

6813 INFLUENCE OF CENTIMETER WAVES ALONE OR COMBINED WITH UV RADIATIONS ON EUKARYOTIC CELLS (MEETING ABSTRACT). (Eng.) Dardalhon, M. (Institut Curie, 26, rue d'Ulm, 75005 Paris, France); Averbeck, D.; Berteaud, A. J. *In: Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France.* p. 5; 1980 (no refs).

The action of centimeter waves (17 GHz at 50 mW/cm² and 9.4 GHz at 5 mW/cm²) on the strain D₊ of the yeast *Saccharomyces cerevisiae* was investigated. No significant effect on survival, the induction of cytoplasmic "petite" mutations, or the induction of mitotic recombination was observed. There was also no effect on sporulation, i.e., meiosis. The results demonstrated that microwaves do not induce genetic effects in nuclear and mitochondrial deoxyribonucleic acid (DNA) and confirmed results of previous studies using millimeter waves (70-75 GHz). To investigate whether microwaves interfere with the repair of lesions induced in cellular DNA by UV radiation, the effects of combined treatments were studied. Exposure to microwaves at 17 GHz (at 50 mW/cm²) and UV irradiation for 1 hr produced biologic effects of small amplitude but with the same tendency compared with the effects produced by UV radiation alone: decrease of survival and increases in mitotic recombination and cytoplasmic "petite" mutations. These effects disappeared as the power was lowered by a factor of 20 and were absent when using microwaves at 9.4 GHz at 5 mW/cm². These effects cannot be explained by the simple heating of the cells. However, it cannot be excluded that they are due to specific thermal effects of the the microwaves. The results are compared to those obtained in interaction experiments with x-rays.

6814 DETECTION OF THE MICROWAVE INFLUENCE ON THE CELL CYTOPLASM FROM FLUORESCENCE POLARIZATION (MEETING

ABSTRACT). (Eng.) More, C. (Groupe de Recherche GR35, CNRS, 2 rue H. Dunant, 94320 Thiais, France); Dardalhon, M.; Berteaud, A. J.; Averbeck, D. *In: Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France.* p. 5; 1980 (no refs).

A method of fluorescence polarization that was used to determine the microviscosity (i.e., the "state") of the cytoplasm after microwave irradiation is described. The fluorescence was observed after enzyme hydrolysis of the nonfluorescent marker fluorescein diacetate in the cytoplasm. The degree of polarization was obtained directly for each sample using automatic recording and a computer device. The results obtained on strain 211 of the yeast *Saccharomyces cerevisiae* after exposure to 2.45-GHz irradiation show that this method can be used for the rapid detection of hyperthermic effects of microwaves on the cytoplasm.

6815 TEMPERATURE DEPENDENCE OF mm-ABSORPTION IN BIOLOGICAL CELLS (MEETING ABSTRACT). (Eng.) Kremer, F. (Max-Planck-Institut für Festkörperforschung, 7000 Stuttgart 80, W. Germany); Genzel, L.; Drissler, F. *In: Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France.* p. 6; 1980 (no refs).

A newly developed millimeter absorption spectrometer is described. An approximately isotropic and homogeneous radiation field is generated in an oversized cylindrical resonator with highly reflective walls, textured inner surfaces, and a rotating mode stirrer. The Q-value of such an oversized multimode resonator is only slightly dependent on the frequency. Radiation passes repeatedly, and from all directions, through an optically thin sample placed inside the cavity. Energy loss is caused only by absorption, but not by scattering from the sample. By measuring the Q-value, with and without the sample, the energy loss of the sample can be determined. With this set-up, the temperature dependence of the absorption (at 53 GHz) in biologic cells (algae, yeast, *Escherichia coli*) was measured in the temperature range from -196 C to 200 C. It is concluded that this type of temperature dependent absorption is a general biologic phenomenon. It is suggested that this may be caused by bound water in the cells, since bound water, at least when absorbed on inorganic substrates, has a freezing point far below that of water.

6816 ELECTROMAGNETIC CONTROL OF CELL REACTIVATION (MEETING ABSTRACT). (Eng.) Beltrame, F. (Biophysical Engineering Section, E.E. Dept., Univ. Genoa, Viale Causa, 13-16145

Genes, Italy); Chiabrera, A.; Grattarola, M.; Ponta, D. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 6; 1980 (no refs).

The problem of cell reactivation in vitro by means of changes of the chemical environment and of suitable electromagnetic exposure is reviewed. The reactivation of two cell classes (differentiated, cycling confluent) is considered. The first step of the reactivation process is the opening of chromatin conformation; this step is dependent on the chemical and electromagnetic microenvironments. The related chromatin conformational changes were measured by automated cytometric methods. The dependence of cell responses on the frequency content of the electromagnetic signal was demonstrated.

6817 COMPARISON OF HYPERTHERMIC CELLULAR SURVIVAL IN THE PRESENCE OR ABSENCE OF 2,450 MHz MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Harrison, G. H. (Dept. Radiation Therapy, Sch. Medicine, Univ. Maryland, Baltimore, MD 21201); Robinson, J. E.; McCulloch, D.; Cheung, A. Y. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 7; 1980 (1 ref).

In vitro cellular survival as a result of heating with or without microwaves was studied. Mammalian cells (CHO) and bacterial cells (*Serratia marcescens*) were exposed at hyperthermic temperatures in glass micropipettes within a water-filled temperature-controlled waveguide exposure chamber. An electric field map indicated that the power density ranged from 158 to 527 mW/cm² for irradiated cells. The colony-forming ability of treated cells was measured as a function of heating time at 43, 44, and 45 C for CHO cells and at 48, 49, and 50 C for *S. marcescens*. Thermal sensitivity, as judged by survival curve slope, approximately doubled for each 1-degree temperature increase. For *S. marcescens*, there was no statistically significant difference between the survival of irradiated and nonirradiated cells. For CHO cells, microwave irradiation produced a statistically significant increase in survival curve slopes--a result equivalent to that expected from an additional 0.37 C increase in temperature of irradiated cells. Thermometry within micropipettes is in progress to study this effect.

6818 CUMULATIVE EFFECT OF MICROWAVES (MEETING ABSTRACT). (Eng.) Tchao, Y. H. (Institut d'Electronique Fondamentale, Université Paris XI, 91405 Orsay cedex, France); Radziszewski, E.; Sauzin-Monnot, M. J. In: *Abstracts of the Proceedings of the International Symposium on the*

Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France. p. 7; 1980 (no refs).

Planaria were repeatedly irradiated (with the time interval between the irradiation equal to 1 hr and 24 hr) in an X-band waveguide to determine whether microwaves have a cumulative effect. Reduction of microwave energy absorption by individual planaria was observed after each session. A sublethal dose of repetitive radiation did not injure the planaria if the time interval between irradiations was \geq 24 hr; for intervals of $<$ 24 hr, repetitive irradiation may produce injury or even death.

6819 BIOLOGICAL EFFECTS OF MICROWAVE EXPOSURE AT DIFFERENT NONTHERMAL LEVELS (MEETING ABSTRACT). (Eng.) Shandala, M. G. (A. N. Marzhev Res. Inst. General and Communal Hygiene, Kiev, USSR). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 10; 1980 (no refs).

Changes in brain bioelectric activity and behavioral reactions of animals, as well as cytochemical and immunologic effects, were studied under long-term microwave exposure to 2.375 MHz at power densities (PD) of 500, 50, 10, 5, and 1 μ W/cm². Unfavorable changes were found in all studied indices at PD of 500 and 50 μ W/cm². Inhibition of the central nervous system (manifested through increased specific weight of the electroencephalogram, slow waves, decreased investigative activity and capacity for work, and inhibited feeding reactions and other behavioral reactions) and the inhibition of immunocompetent cells functional activity, accompanied by the tension of energy metabolism in neutrophils, were observed. A PD of 10 μ W/cm produced certain biologic activity, which recovered after termination of the exposure, suggesting that compensatory and adaptative reactions in organisms occur at this radiation level. These data may be used as an experimental basis for hygienic standards of microwave exposure.

6820 CHRONIC LOW-LEVEL EFFECTS IN RABBITS EXPOSED TO 2,450 MHz MICROWAVE RADIATION (MEETING ABSTRACT). (Eng.) Chou, C. K. (Bioelectromagnetics Res. Lab., Dept. Rehabilitation Medicine, Sch. Medicine, Univ. Washington, Seattle, WA 98195); Guy, A. W.; Borneman, L.; Kunz, L. L. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 10; 1980 (no refs).

Thirty-two male New Zealand rabbits were exposed to 2.450 MHz continuous wave microwave fields in

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two separate periods of 90 days each. The incident power density of the first and second period was 0.5 and 5 mW/cm², respectively. During each study, 16 animals were adapted to a miniature anechoic chamber exposure system for 2 wk, and then 8 animals were dorsally exposed, individually in the anechoic chamber, for 7 hr/day, 5 days/wk for 13 wk; the remaining 8 animals were sham-exposed. Thermographic data showed a maximum specific absorption rate of 5.45 W/kg in the head and 14 W/kg in the back of the rabbit for the 5 mW/cm² incident power density. After each 7-hr session, the animals were returned to their cages. Body wt and food consumption in the exposure chamber were measured daily. Blood samples were taken before exposure and monthly thereafter for hematologic, chemical, morphologic, protein electrophoresis, and lymphoblast transformation studies. Eyes were examined for cataract formation. Pathologic examinations on 31 specimens of organs and tissues were also performed. Statistically, there were no consistent significant differences in measured parameters observed between the exposed and the sham-exposed animals. However, there was a 20% reduction of mean food consumption in the exposure cages ($p < 0.05$). Despite the lower food intake in the exposure cage, the body wt of the exposed group was similar to that of the sham-exposed group. The glucose level was slightly but consistently higher in the exposed group.

6821 THE EFFECT OF HIGH-FREQUENCY ELECTROMAGNETIC FIELD ON THE FROG NEUROMUSCULAR PREPARATION (MEETING ABSTRACT). (Eng.) Tigranyan, R. E. (Inst. Biological Physics, Acad. Sciences USSR, Pushchino, USSR); Khafisov, R. Z.; Tyazhelov, V. V. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 11; 1980 (no refs).

The time dependence of the excitement transmission in a frog neuromuscular preparation under regular stimulation was investigated. At a sufficiently low stimulation frequency (1 Hz), the transmission was blocked some minutes after the onset of excitation. Irradiating the preparation with microwaves (800 MHz, power density 12 mW/cm²) simultaneously with the stimulation removed the block of excitation transmission for a long time period.

6822 DECREASE IN HEART FREQUENCY AFTER EXPOSURE TO A MICROWAVE FIELD IN THE WHITE RAT (MEETING ABSTRACT). (Eng.) Servantie, B. (EASSM-CERB, Hopital d'Instrumentation des Armees Sainte-Anne, 63800 Toulon-Naval, France); Creton, B.; Brushera, D.; Roussel, J. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of*

Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France, p. 11; 1980 (no refs).

White rats were exposed to 2.45-GHz, 3-GHz, and 9.4-GHz frequency microwave fields for exposure durations between 5 and 15 days. The incident average power density in far field was 5 mW/cm². Electrocardiographic and electrocardiographic records were made. Irradiated animals had a heart frequency lower than those of control animals. The decrease was more important for animals exposed to the 3-GHz field.

6823 EFFECTS OF MICROWAVE EXPOSURE ON ANESTHESIA IN THE MOUSE (MEETING ABSTRACT). (Eng.) Blackwell, R. P. (Natl Radiological Protection Board, Didcot, Oxon, Harwell OX11 ORQ, England). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 12; 1980 (no refs).

The effects of 2.45-GHz far-field microwave exposure on sodium hexobarbitone and Althesin anesthesia in the mouse were studied. A dose-dependent reduction in duration of hexobarbitone anesthesia was seen at thermogenic power densities of 250 and 500 Wm⁻², compared with sham exposure. No significant effect on Althesin anesthesia was seen at either power density. Since stress, reflected by increased blood corticosterone levels, has been shown to reduce hexobarbitone-induced sleeping time, measurements of plasma corticosterone were made in mice anesthetized with hexobarbitone. Both 250- and 500-Wm⁻² exposures produced significantly lower levels than sham exposed controls. Thus, a stress-mediated effect is not implicated.

6824 INFLUENCE OF THE MICROWAVE EXPOSURE TIME ON TRIGLYCERIDEMIA IN THE MOUSE (MEETING ABSTRACT). (Eng.) Dumas, J. C. (CERT/DERMO, 2, avenue E. Belin, B.P. 4025, 31055 Toulouse cedex, France); Nougarol, D.; Plurien, G.; Stoll, M. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 12; 1980 (no refs).

The kinetics of the rise in serum triglycerides in mice exposed to microwave radiation were studied. The mice were irradiated with continuous wave microwaves at 2.450 MHz at power densities of 8 ± 2 or 12 ± 2 mW/cm². The results showed that the effect of continuous exposure occurred rapidly. The maximal effect, however, was only reached after a 9-day period and remained stable thereafter. When the animals were no longer exposed, the triglyceride level decreased to reach its initial value within 48 hr, suggesting that the change in lipid metabolism is

rapidly reversible. The effect of a repeated rather than continuous exposure was far less intense. Thus, the variation of triglyceride level in the mouse induced by continuous exposure to microwave radiation is a rapid, long-lasting but reversible phenomenon. Its amplitude is diminished for repeated exposures.

6825 EFFECT OF 2.45 GHz MICROWAVE RADIATION ON EMBRYONIC QUAIL HEARTS (MEETING ABSTRACT). (Eng.) Galvin, M. J. (Lab. Environmental Biophysics, Natl. Inst. Environmental Health Sciences, P. O. Box 12233, Research Triangle Park, NC 27709); McRee, D. I., Lieberman, M. In *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 13, 1980 (no refs).

The effect of microwave radiation on cardiogenesis of Japanese quail embryos exposed during the first 8 days of development to 2.45-GHz continuous wave microwaves at an incident power density of 5 mW/cm² or 20 mW/cm² was studied. The specific absorption rates were 4.03 and 16.2 mW/g, respectively. The ambient temperature for each exposure was set to maintain the embryonated eggs at 37.5°C. The results showed that neither exposure level was capable of inducing changes in either the morphology of the embryonic heart or the ultrastructure of the myocardial cells. A comparison of the enzyme activities of lactate dehydrogenase (LDH), glutamic oxaloacetic transaminase (GOT), and creatinine phosphokinase (CPK) failed to reveal any statistical difference between the nonexposed controls and the exposed groups. The values obtained for each enzyme expressed relative to 100 µg protein were as follows: LDH, 650 Wroblewski units; GOT, 120 Karmen units; and CPK, 275 IU. These data indicate that 2.45-GHz microwave irradiation at 5 or 20 mW/cm² had no effect on the measured parameters of the Japanese quail myocardium during the first 8 days of development.

6826 STUDIES OF MOUSE TESTIS CYTOLOGY FOLLOWING 30 DAYS EXPOSURE TO 2,450 MHz CW (MEETING ABSTRACT). (Eng.) Harding, R. K. (Radiation Biology Section, Defense Res. Establishment, Ottawa, Ontario K1A 0Z4 Canada); Cairnie, A. B. In *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 13, 1980 (no refs).

Two groups of 18 male mice were housed singly and exposed to 2.450-MHz continuous wave radiation in an anechoic chamber, 16 hr/day for 30 days. The average exposure for the two groups was 36 and 37 mW/cm². There were two groups of 18 unexposed

controls. No changes were seen in the sperm count or percent abnormal sperm assay, at intervals up to 8 wk after exposure. No changes in vital-dye exclusion by a suspension of testicular cells were seen following the 30-day exposure. Cooling curve extrapolations performed on mice killed immediately after a 16-hr exposure to 50 mW/cm² indicated no significant increase in intratesticular temperature. Miniature E-field probe measurements predict a specific absorption rate (SAR) of 13.6 (+40%) W/kg in the testis of a mouse exposed to 50 mW/cm². The SAR in testis did not vary significantly with the orientation of the mouse.

6827 EFFECTS OF MICROWAVE NEONATAL EXPOSURE ON THE DEVELOPMENT OF CORTICOTROP AND GONADOTROP FUNCTIONS IN THE RAT (MEETING ABSTRACT). (Eng.) Manley, J. (Laboratoire de Physiologie des Régulations, Campus de Beaulieu, 35042 Rennes cedex, France); Le Ruz, P. In *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 14, 1980 (no refs).

Male rats were exposed 15 days after birth to pulsed microwave radiation at 3.5 GHz, of mean power density 10 mW/cm². Body wt and testicle and adrenal wt increased more than that of controls over the first 2 mo of life. The growth rate then decreased and at 3 mo the weight of the glands was lower than for controls. Histologic studies suggested some perturbation in spermatogenesis. At all developmental stages (1, 1.5, 2, and 3 mo), neonatal irradiation diminished the content of adrenocorticotrophic hormone in the pituitary, modified the gonadotrophin (follicle-stimulating hormone and luteinizing hormone) content in the pituitary, and slightly but consistently increased the plasma concentration of these two hormones. The concentration of corticosterone in the adrenals was 3 to 5 times greater at 3 mo. The hypothesis that microwave irradiation induces a perturbation in the hypothalamus in the neonatal period is discussed.

6828 NONLINEAR OSCILLATIONS IN BIOLOGICAL MODEL SYSTEMS INTERACTIONS WITH EXTERNAL FIELDS (MEETING ABSTRACT). (Eng.) Kaiser, F. (Inst. Theoretical Physics, Univ. Stuttgart, Pfaffenwaldring 57, 7000 Stuttgart 80, W. Germany). In *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 16, 1980 (no refs).

The following concepts are analyzed and the results of calculations are presented with special emphasis on the effects of frequency and intensity on the quenching of nonlinear oscillations of the limit

cycle type (LC). 1) Observable biologic oscillations must be stable LCs, including sets of coupled LCs. 2) Stable LCs are a suitable basis to model coherent oscillations in active biologic systems. 3) Stable LCs may be important to describe effects of external fields on biologic systems. The LC concept reveals a possible explanation of the experimentally found specific sensitivities of biologic systems to a weak external stimulus: i.e., only a small amount of external energy is necessary to create a response since the inherently stored LC energy will build up the signal. This concept is applied to some model systems: 1) the generalized Van der Pol oscillator to describe threshold and excitability, 2) the coherent oscillation model to describe extreme sensitivity of brain function, and 3) the high polarization model to discuss energy exchanges between oscillating biomolecules.

6829 TWO TYPES OF MICROWAVE AUDITORY SENSATION AND THEIR POSSIBLE MECHANISMS (MEETING ABSTRACT). (Eng.) Khizhnyak, E. P. (Inst. Biological Physics, Acad. Sciences USSR, Pushchino, Moscow, USSR); Shorokhov, V. V.; Tyazhelov, V. V. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 16; 1980 (no refs).

Experimental data pointing to the existence of two types of auditory sensory effects are considered. The thermoelastic theory by A. Guy and J. Lin accounts for only one of these effects. A model that can form the basis of the mechanism of the second type of radio sound is suggested.

6830 PECULIARITIES OF MICROWAVE EFFECT ON GRAMICIDIN MODIFIED BILAYERS (MEETING ABSTRACT). (Eng.) Tyazhelov, V. V. (Inst. Biological Physics, Acad. Sciences USSR, Pushchino, Moscow, USSR); Alekseev, S. I.; Faizova, L. K.; Chertishev, V. V. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 17; 1980 (no refs).

Peculiarities of microwave effects on conductivity of gramicidin modified bilayers are described. Data on the value of conductivity changes and peculiarities of their kinetics are given. The value of conductivity changes are determined by the total ionic strength rather than by the ion-carrier concentration. The observed relations correspond to the "microheating" mechanism of the effect.

6831 INDUCTION OF CALCIUM ION EFFLUX FROM BRAIN TISSUE BY RADIO FRE-

QUENCY RADIATION: EFFECT OF A 50 MHZ CARRIER FREQUENCY ON THE POWER DENSITY DEPENDENCE (MEETING ABSTRACT). (Eng.) Blackman, C. F. (Health Effects Res. Lab., EPA, Research Triangle Park, NC 27111); Benane, S. G.; Joines, W. T.; Hollis, M. A.; House, D. E. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 17; 1980 (no refs).

The effect of radio frequency radiation on the calcium-ion binding of brain tissue exposed to power densities of a 50-MHz carrier, amplitude modulated by a 16-Hz sine wave, was reported. Brain samples were treated *in vitro* in a Crawford cell; four brain tissues plus six dummy loads were exposed together to broaden any power window and to enhance the opportunity for detection of changes in the calcium-ion binding kinetics. The results of a power density series demonstrated two effective ranges one included 1.44 and 1.67 mW/cm² and the other included 3.64 mW/cm², bracketed by no-effect results at 0.72, 2.17, and 4.32 mW/cm². Possible reasons for the marked difference between these results and those obtained using higher carrier frequencies are discussed.

6832 THE EFFECTS OF CW MILLIMETER WAVE IRRADIATION ON MITOCHONDRIAL OXIDATIVE PHOSPHORYLATION AND Ca⁺⁺ TRANSPORT (MEETING ABSTRACT). (Eng.) Motzkin, S. M. (Polytechnic Inst. New York, 333 Jay St., Brooklyn, NY 11201); Melnick, R.; Rubenstein, C.; Rosenthal, S.; Birenbaum, L. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 18; 1980 (no refs).

The effects of continuous wave (CW) millimeter wave irradiation on oxidative phosphorylation and Ca⁺⁺ transport in freshly prepared rat liver mitochondria were examined at 8.58 mm (35 GHz) and at 41 discrete wavelengths between 5.00 and 6.00 mm (60-50 GHz). Millimeter wave exposure systems using waveguide components that monitor power density, reflections, and frequency stability were employed. Mitochondrial suspensions were exposed for 15 min at 8.58 mm and subsequently evaluated for their efficiency in coupling succinate oxidation to phosphorylation of adenosine diphosphate. Changes in respiratory control ratios observed at 250, 500, and 1,000 mW/cm² at 30 °C indicated membrane damage. At 25 °C, respiratory control ratios were maintained at higher exposure levels and at 4 °C, some coupling of the mitochondria was maintained even at 1,000 mW/cm². A new assay was developed to evaluate CW millimeter effects on actively phosphorylating mitochondria. This technique involved a quantitative determination of adenosine triphosphate (ATP) synthesis linked to succinate oxidation. No difference in

ATP synthesis was observed when mitochondria were irradiated at 25°C for 2 min at 8.58 mm from .01 to 1,000 mW/cm² or at 5.0-6.0 mm at 5 mW/cm². Uptake and efflux of calcium were also examined in carrier-mediated succinate driven transport studies. Mitochondrial suspensions irradiated at 25°C at 8.58 mm and 5.00-6.00 mm at power densities of 1-1.000 and 5 mW/cm², respectively, were evaluated for their ability to couple a proton gradient to Ca⁺⁺ uptake and efflux. At 8.58 mm, changes in "Ca uptake after 15 min and efflux after 5 min of irradiation were not observed below 100 mW/cm². Above 100 mW/cm², decreased uptake and increased efflux were correlated with membrane damage due to thermal changes. No differences in uptake or release were noted in the 5.00- to 6.00-mm range.

6833 CALCIUM DEPENDENT SECRETORY PROTEIN RELEASE AND CALCIUM EF-FUX, AFTER VHF ELECTROMAGNETIC RADIATION OF RAT PANCREATIC SLICES (MEETING ABSTRACT). (Eng.) Albert, E. N. (Dept. Anatomy, Medical Center, George Washington Univ., Washington, DC 20037); Blackman, C. F.; Slaby, F. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 18; 1980 (no refs).

The effects of 147-MHz radiation, amplitude modulated at 16 Hz, on rat pancreatic tissue slices were investigated. The field incident energy was 2 mW/cm² and the specific absorption rate was estimated at <0.1 mW/g. After 60 to 150 min of irradiation of pancreatic tissue slices (incubated in HEPES buffered medium under 100% O₂ atmosphere), the release of pulse-labeled secretory proteins and "Ca⁺⁺ efflux was measured. The data, collected in a Crawford cell exposure facility, demonstrated that 147 MHz electromagnetic radiation, sinusoidally modulated at 16 Hz, caused an 11% increase in "Ca⁺⁺ efflux from pancreatic tissue when compared to sham exposed samples. However, the radiation did not affect the calcium dependent release of pulse-labeled protein from either control or carbamylcholine stimulated tissue slices. The lack of calcium dependent protein release raises some questions about the physiologic significance of the increased calcium efflux.

6834 THE EFFECT OF MICROWAVE IRRADIATION ON RAT SERUM PEROXIDASE ACTIVITY (MEETING ABSTRACT). (Eng.) Mezykowski, T. (Military Inst. Aviation Medicine, Krasinskiego 54, 01-755 Warszawa, Poland). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 19; 1980 (no refs).

The influence of 2.2-2.32-GHz microwaves (power density 2-3 mW/cm²) on the activity of rat serum peroxidase was investigated. There was a marked decrease in the rate of product formation in the exposed group as compared to the control group. Some effects on the enzyme-substrate affinity (measured as K_m and V_{max} values) in irradiated samples were also observed. The results may indicate conformational modification of the enzyme molecule.

6835 BIOCHEMICAL STUDIES OF THE COMBINED EFFECT OF ANTICHOLINESTERASE AND MICROWAVE RADIATION ON THE BLOOD BRAIN BARRIER IN THE RAT (MEETING ABSTRACT). (Eng.) Ashani, Y. (Armed Forces Radiobiology Res. Inst., Defense Nuclear Agency, Bethesda, MD 20014); Catravas, G. N. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 19; 1980 (no refs).

Low level microwave irradiation was found to enhance the biologic activity of anticholinesterase drugs such as phospholine iodide and paraoxon in the rat. The observed changes were measured in terms of hypothermia that developed after administration of the drug followed by exposure of the animals to the microwave field. Hypothermia also developed when the anticholinesterase antidote 2-pyridine aldoxime methiodide was administered under the same conditions as the anticholinesterase. Paraoxon induced significant changes in the blood-brain barrier whereas phospholine iodide did not seem to affect this biologic target. The biochemical evidence on the blood-brain barrier changes as indicated by acetylcholinesterase level measurements could not be quantitatively correlated with the low level microwave enhancement of the hypothermia induced by the above drugs.

6836 THE EFFECTS OF LOW-LEVEL RF RADIATION ON THE BLOOD BRAIN BARRIER IN MICE AND RATS: AN ELEVATION OF NATURALLY-OCCURRING AMINO ACIDS IN MOUSE BRAIN (MEETING ABSTRACT). (Eng.) Spackman, D. H. (Pacific Northwest Res. Foundation, Seattle, WA 98104); Riley, V.; Guy, A. W.; Chou, C. K. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 20; 1980 (no refs).

The effects of radio frequency radiation (RFR) on altering concentrations of naturally occurring amino acids in the brain were investigated in mice. Fasted animals were exposed to pulsed RFR at 918 MHz (average power density, 10 mW/cm²; pulse frequency, 500 pulses/sec; pulse width, 2 μ sec, and average

specific absorption rate for mice, 2.1 W/kg). Deproteinized extracts of plasma and of brain homogenates were then analyzed on an amino acid analyzer. Similar samples from nonirradiated, fasted controls were also examined. Of the seven natural amino acids analyzed, six were significantly statistically elevated in the brains of irradiated animals. Phenylalanine was increased two-fold. Two amino acids that were elevated in the brain were absent in plasma, and the plasma levels of the others did not change. Thus, in addition to active transport across the blood-brain barrier, there may be other mechanisms that can increase brain concentrations of specific compounds in conjunction with RFR. An alternate possibility is that increased levels of amino acid precursors, derived either from plasma or from brain metabolism, are then transaminated, decarboxylated, etc., in the brain. Since increased levels of brain amino acids have also been observed in sham-irradiated mice, stress-evoked elevations of plasma corticosterone resulting from RFR and experimental treatment may play a role.

6837 MODIFICATION OF ACUTE STAPHYLOCOCCAL INFECTIONS BY LONG-TERM EXPOSITION TO LOW-LEVEL MICROWAVE FIELDS OR WHOLE BODY MICROWAVE HYPERTHERMIA (MEETING ABSTRACT). (Eng.) Szmigelski, S. (Dept. Biological Effects of Nonionizing Radiation, Center for Radiobiology and Radioprotection, 00-909 Warsaw, Poland); Roszkowski, W.; Jeljaszewicz, J. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 22; 1980 (no refs).

Mice and rabbits were irradiated with 2.450 MHz microwaves (MW) at a mean power density of 5 or 15 mW/cm² (anechoic chamber, far-field conditions), 2 hr/day for 6 or 12 wk. Other mice were exposed to whole-body MW hyperthermia (increase of rectal temperature to 42.5 ± 0.5 C) at mean power density of 40-60 mW/cm², 2 hr/day for 4, 7, 10, or 14 days. One day after termination of exposure to MW or hyperthermia, the animals were infected intravenously with viable *Staphylococcus aureus*. Functional tests of granulopoiesis (blood granulocytosis, release of bone marrow reserve pool, serum lysozyme activity and nitro-BT reduction by blood granulocytes), phagocytosis of ³P-labeled bacteria by peritoneal macrophages, delayed hypersensitivity to oxazolone, and reactivity of spleen lymphocytes to phytohemagglutinin and lipopolysaccharide were investigated before infection (effect of exposure to MW) and every second day after infection. The mortality rate (mice only) was evaluated daily. Long-term exposure to 2.450 MHz MW at 15 mW/cm² led to impaired function of nonspecific defense (slower kinetics of granulopoiesis, weakened phagocytosis by macrophages) resulting in turn in aggravation of clinical course of experimental staphylococcal infec-

tions and increased mortality from the infection. The specific cellular immunity did not change under these conditions. At 5 mW/cm², increased phagocytosis was found, however, no significant changes either in kinetics of granulopoiesis or specific cellular immunity were observed. Whole-body MW hyperthermia lasting 7-14 days resulted in lowering of natural bacterial resistance (slower clearance of microorganisms from peripheral blood, weakened phagocytosis by macrophages) and higher mortality from staphylococcal infections. This was accompanied by suppression of specific cellular immunity.

6838 EFFECTS OF PULSED 3 GHz MICROWAVES ON THE IMMUNOLOGICAL CHANGES OF MICE, IN VIVO (MEETING ABSTRACT). (Eng.) Draussin, M. (Service Central de Medecine Nucleaire, Centre Hospitalier Regional, Universitaire de Nimes, 5 rue Hoche, B.P. 26, 3006 Nimes cedex, France); Chevalier, J. M.; Gouget, P.; Serre, L.; Servantie, B.; Miro, L. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 22; 1980 (no refs).

Sixty Swiss male mice were exposed in an anechoic chamber for 15 days to pulsed 3-GHz microwave fields (duty cycle, 525 Hz; pulse width, 1 μ sec; mean power density, 1-2 mW/cm²). Sixty Swiss male mice served as controls. The humoral change observed after an intravenous injection of sheep red blood cells (10^8 red cells) was analyzed in 20 controls by a seroagglutination test. Delayed hypersensitivity to sheep red blood antigen was analyzed in 40 exposed and 40 control mice by the foot pad technique. No significant difference between the behavior of controls and exposed animals was found. Histologic examination of liver, bone marrow, lymph nodes, spleen, and thymus revealed no thermal injury. Agglutinin titers were significantly increased ($p < 0.05$) from the 6th day after the beginning to the 15th day after the end of irradiation. Delayed hypersensitivity was significantly increased for exposed animals in relation to the controls only between the 10th and 15th day of irradiation ($p < 0.01$). Histologic studies confirmed results obtained in earlier experiments: i.e., an increased mitotic lymphocyte index in the thymus and better individualization of Malpighi corpuscles into the spleen.

6839 STUDIES OF IMMUNE RESPONSE IN THE MOUSE AFTER MICROWAVE RADIATION OF 2,450 MHz (MEETING ABSTRACT). (Eng.) Deschaux, P. (Laboratoire de Physiologie Cellulaire, Universite Cl. Bernard, 69621 Villeurbanne, France); Dumont, J. M.; Ivanoff, B.; Pellissier, J. P.; Fontanges, R. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of*

Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France. p. 23; 1980 (no refs).

Swiss male mice (2 mo old) were exposed to 2.45-GHz microwave radiation at various power densities (10, 5, and 1 mW/cm²) in a multimode cavity for 4 hr/day for 5 days. Stimulation of humoral immunity was observed at power densities between 1 and 5 mW/cm². The protecting effect of the vaccine *Salmonella typhimurium*, Rc mutant, was not modified.

6840 THE EFFECT OF A UNIFORM CONSTANT MAGNETIC FIELD ON SPLENIC INDEX OF HEALTHY MOUSE AND IRRADIATED MOUSE (MEETING ABSTRACT). (Eng.) Bellossi, A. (Laboratoire de Biophysique, Av. du Pr. L. Bernard, 35043 Rennes cedex, France); de Certaines, J.; Tchuempe Tchuente, G.; Ruelloux, M.; Poubanne, B. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France. p. 23; 1980 (no refs).*

The splenic index (SI) was measured in Swiss mice subjected to a uniform constant magnetic field (MF) of intensity 0.05-0.8 Tesla for 2 hr/1x/day or for 2 hr/1x every 2, 3, or 4 day. The mice were either healthy or previously irradiated with 25 million electron-V (MeV, at a lethal dose). MF exposure did not modify healthy mice SI. Irradiation with 25 MeV caused a dramatic decrease of SI. Postirradiation MF exposure resulted in a temporary increase in the SI; this effect was found when the MF exposure occurred 1x during the 4 days after the irradiation. A second MF exposure was efficient only after more than 24 hr of the first exposure. Spleen aqueous retention, local protective effects, or a cell draining from bone marrow, does not explain the observed SI increase following MF exposure of irradiated mice.

6841 MICROWAVE RADIATION (2,450 MHz) ALTERS THE ENDOTOXIN-INDUCED HYPOTHERMIC RESPONSE OF RATS (MEETING ABSTRACT). (Eng.) Smialowicz, R. J. (Health Effects Res. Lab., EPA, Research Triangle Park, NC 27711); Compton, K. L.; House, D. E.; Riddle, M. M.; Rogers, R. R.; Brugnolotti, P. L. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France. p. 24; 1980 (no refs).*

Rats injected with endotoxin were exposed, under controlled environmental conditions (22 C and 50% relative humidity), to 2.450 MHz continuous wave microwaves (incident power densities of 10, 5, or 1 mW/cm²; specific absorption rate of 1, 0.5, and 0.1 W/kg, respectively) during the hypothermic period. Rectal temperatures were measured before and im-

mediately after the 90-min treatment period. The change in body temperature was calculated for each rat. Statistically significant differences were observed in the mean temperature change of endotoxin-injected rats irradiated at levels as low as 1.0 mW/cm² compared to endotoxin-injected sham-irradiated rats. Following the administration of endotoxin rats were rendered ectothermal in their response to thermal energy. The observed alteration in the hypothermic response of rats to endotoxin was apparently due to the thermal properties of microwave radiation since endotoxin-injected rats held at environmental temperatures of ≥ 26 C had rectal temperatures significantly higher than rats held at 22 C. Consequently, very subtle thermal energy input by microwaves was detectable with this model. These results indicate that claims for "nonthermal" microwave-induced bioeffects in laboratory rodents exposed at low intensities (≤ 10 mW/cm²) should be evaluated more prudently.

6842 EFFECTS OF LOW DIRECT CURRENT ON MONOMOLECULAR LAYERS OF METAL STEARATES COATING ELECTRODES IN BACTERIAL CULTURES AND ON SURGICAL IMPLANTS (MEETING ABSTRACT). (Eng.) Colmano, G. (Virginia Polytechnic Inst., Blacksburg, VA 24061); Edwards, S. S.; Barranco, S. D. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France. p. 24; 1980 (no refs).*

A study of possible intra- and extracellular interactions of electromagnetic energy on molecular ions and their behavior at cellular membrane interfaces, induced by changes in experimental design, was attempted. The effects of pure metals (Ag, Al, Au, Cu, Pt) or stainless steel or glass electrodes, coated with monolayers of different metal stearates (of Ag, Al, Au, Ba, Cr, Cu, Li, Ni, P, S, Sn, Sr, alone or in different combinations) and with or without contamination by bacterial cultures (*Staphylococcus aureus*, *Proteus vulgaris*, *Pseudomonas aeruginosa*), were tested in vitro (in broth and agar) and in vivo (in the femurs of rabbits and dogs). The responses to electrodes, not activated or activated by low-positive or negative direct current, were charted for their inhibition or enhancement of cellular growth. A nanomolar concentration of silver from current activated silver electrodes had bacteriocidal effects in vitro and in vivo. As a practical result, 1 hr of 12 μ amp of positive direct current/cm² on 100 monolayers of silver stearate on stainless steel were found to inhibit possible osteomyelitis infections by approximately 3,000 *Staphylococcus aureus* in dog femurs.

6843 BIOLOGICAL EFFECTS OF EXTREMELY LOW-FREQUENCY NON-IONIZING RADIATION (MEETING ABSTRACT) (Eng.) Aarholt, E.

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(Dept. Electrical Engineering, Univ. Salford, Salford, M5 4WT, England). Flinn, E. A.; Smith, C. W. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 25; 1980 (2 refs).

Bacteria (*Escherichia coli*, *Staphylococcus albus*, and *Chromobacterium lividum*) were grown under controlled conditions in magnetic fields ranging from 0 to several kG. Preliminary results indicated that the effects of direct current magnetic fields on *E. coli* are much less than those reported by other workers. However, it appeared that the growth rate of *E. coli* was depressed by fields between 1 and 2 kG, but increased by fields less than 1 kG or greater than 2 kG. For fields above 2.5 kG, the temperature tolerance of *E. coli* was significantly increased.

6844 EFFECTS OF A WEAK CONSTANT MAGNETIC FIELD UPON HUMAN FOREHEAD (Eng.) Masterman, W. D. (Univ. Texas at Dallas, 1800 First Natl. Bank Building, Dallas, TX 75202). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 25; 1980 (1 ref).

Thirty-four humans were exposed on a blind basis to a weak (5,000 gamma) constant magnetic field. Each subject served as his own control. Group forehead skin temperature asymmetries were highly significant ($p < 0.01$) in both the exposure and after-effect trials of the field-on session. Asymmetries were determined by paired sample *t* tests on the simultaneous differences between the left and right forehead temperatures. Differences in forehead temperature levels were interpreted as lateralized changes in intracranial blood flow. A significant increase in group left forehead temperature and decrease in variance occurred in the after-effect trial of the field-on session. These data were analyzed postexperimentally by dividing the subjects into three categories depending on whether an individual showed a significant left forehead temperature increase, a decrease, or no significant change. This procedure divided the group into three almost equal categories that showed distinctly different temperature (blood flow) and verbal anxiety field effects. These results suggested that (1) forehead skin temperature may constitute a simple and effective marker variable for detecting weak field effects and (2) it may be critical in designing experiments to classify humans by autonomic reactivity patterns before testing for possible field effects on autonomic variables.

6845 ENHANCEMENT OF CHEMICALLY 3,4-BENZOPYRENE-INDUCED SKIN CANCER DEVELOPMENT IN MICE BY LONG-TERM LOW-

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LEVEL EXPOSURE TO 2,450 MHz MICROWAVES (MEETING ABSTRACT). (Eng.) Szudzinski, A. (Dept. Dermatology, Military Postgraduate Medical Center, Warsaw, Poland); Pietraszek, A.; Roszkowski, W.; Szmigelski, S. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 26; 1980 (no refs).

BALB/c mice were treated with 3,4-benzopyrene (BP, painting of skin with 0.01 ml of 1% BP in acetone every second day) to induce skin cancer, and then exposed to 2,450 MHz microwaves (MW, anechoic chamber, far-field conditions, field power density 5 or 15 mW/cm², 2 hr/day) at different periods before or during BP treatment. The following groups (20 animals per group) were studied: a) MW irradiation during 3 or 6 mo simultaneously with BP exposure, 4 groups; b) MW irradiation during 1, 2, or 3 mo before BP exposure, 6 groups; and c) controls, normal and sham irradiated mice exposed to BP, 4 groups. Monitoring of cell mediated immune reactions (delayed hypersensitivity to oxazolone, number of T lymphocytes, reactivity of spleen lymphocytes to phytohemagglutinin and lipopolysaccharide), as well as ability of peritoneal macrophages for phagocytosis were tested, 2, 4, 6, and 8 mo after BP exposure. Irradiation of mice with 2,450 MHz MW at 15 mW/cm² significantly hastened development of skin cancer and shortened survival of mice treated with BP (mean cancer development time, 291 ± 34 days in controls and 204 ± 22 in MW-exposed mice). Development of skin cancer was accompanied by lowering of delayed hypersensitivity reaction to oxazolone and depressed phagocytosis. No significant differences in cancer development were observed between mice irradiated with MW at 15 mW/cm² and those irradiated at 5 mW/cm²; simultaneously with BP treatment, however, exposure to MW prior to treatment with BP (either 5 or 15 mW/cm²) did not significantly influence development of skin cancer.

6846 THE EFFECT OF 5.62 GHz MICROWAVES ON REPEATED ACQUISITION OF RESPONSE SEQUENCES IN SQUIRREL MONKEYS (MEETING ABSTRACT). (Eng.) de Lorge, J. (Naval Aerospace Medical Res. Lab., Pensacola, FL 32508); Knepton, J. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 28; 1980 (no refs).

The effects of 5.62-GHz microwaves pulsed at power densities of 17 to 46 mW/cm² on four male squirrel monkeys, *Saimiri sciureus*, ability to learn sequences of three responses were studied. The response sequence was rearranged daily resulting in a repeated acquisition of the response sequence by a monkey. The monkeys performed the task while being exposed to the microwaves. No behavioral effects were observed at power densities of 17 and 32 mW/cm², but performance was disrupted at 38 and 46

mW/cm². Learning, per se, which occurred early in a session, was not primarily affected; the major effect was on performance, which deteriorated in the latter portions of a 60-min session after a sequence had been learned. Colonic temperature increased with increases in power density. No permanent effects of the microwaves on behavior were found. The specific absorption rates of energy absorbed in both saline and flesh-simulating models was also obtained. The normalized specific absorption rate in the saline model was 0.18 W/kg/mW/cm². It is concluded that although no intrinsic effect of microwaves on learning occurred, a definite effect on performance occurred at the 38 mW/cm² level and this effect was associated with a rise in colonic temperature at 1°C or more.

6847 EVALUATION OF THE EFFECTS OF A 2.45 GHz CW RADIATION ON THE MOTOR ACTIVITY AND THE BLOOD COUNT OF THE MOUSE C57BL6 (MEETING ABSTRACT). (Eng.) Klein, M. J. (Division de Neurophysiologie Applique, Centre d'Etudes et de Recherches de Medecine Aerospatiale, 26 Bld. Victor, 75996 Paris Armees, France); Milhaud, C. L.; Nathie, J. G.; Charrieau, J. L. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 28; 1980 (no refs).

The effects of a short microwave radiation (14 hr/day) repeated for 4 and 5 days on the motor activity and the blood count of male C57BL6 mice were investigated. The individual and simultaneous motor activity of a pair of subjects (irradiated + control) was registered for 1 hr in four groups of mice: following the radiation (2.45 GHz, continuous wave, 5 ± 2 mW/cm²) and after 1, 4, and 6 hr. Blood was sampled after the motor activity session. A variance-analysis of the findings relative to 160 subjects (four groups of 20 subjects, controls + irradiated) showed that the motor activity was significantly reduced in the irradiated subjects ($p < 0.01$) for the first 30 min and that the dynamics of the motor activity were disturbed 0, 1, and 4 hr following irradiation. No effect related to the irradiated time was noted or on blood count perturbations. The effects observed on the innate behavior of the mouse confirm some synchronizing effects of microwaves previously reported. The generally described effects are confirmed by the lack of change in the hemogram following low-level irradiation.

6848 MICROWAVE MODIFICATION OF THERMOREGULATORY BEHAVIOR: EFFECTS OF EXPOSURE DURATION (MEETING ABSTRACT). (Eng.) Adair, E. R. (John B. Pierce Foundation, New Haven CT 06519). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects*

of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France. p. 29; 1980 (no refs).

To determine the effect on thermoregulatory behavior, squirrel monkeys were exposed to 2.450-MHz continuous wave (CW) microwaves (E polarization) at a power density of 4 and 10 mW/cm² (specific absorption rate 0.6 and 1.5 W/kg, respectively) for periods ranging from 5 to 25 min. Monkeys were restrained in the far-field of a horn antenna inside a 1.8 x 1.8 x 2.5 m anechoic chamber that was heated and cooled by forced convection. The animals learned to control the temperature of the circulating chamber air by selecting between two preset air temperatures, 15 and 55°C. No microwaves were present during 4-hr control experiments. The 4-mW/cm² microwave exposure did not modify thermoregulatory behavior. The 10-mW/cm² exposure stimulated the monkeys to select an ambient temperature 2.5-3.0°C cooler than control levels ($p < 0.01$). Except for the first microwave presentation of each experimental session, exposure duration had no significant effect on the air temperature selected or the resulting body temperatures.

6849 FAILURE TO DISRUPT MAZE LEARNING IN RATS BY POST-TRIAL EXPOSURE TO MICROWAVES (MEETING ABSTRACT). (Eng.) Lovely, R. H. (Dept. Rehabilitation Medicine, RJ-30, Medical Sch., Univ. Washington, Seattle, WA 98195); Gesford, J.; Guy, A. W. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 29; 1980 (no refs).

The effect of microwaves, 915 MHz, circularly polarized and square-wave modulated at 11 Hz, with an average incident power density of 1.25 mW/cm² and a peak power of 2.5 mW/cm² (specific absorption rate approximately 0.5 W/kg), on maze learning behavior in rats was investigated. Albino rats were trained to acquire a position discrimination for food reward in a T-maze until they had run to the correct position six out of eight trials for 2 days. After reaching this criterion the position of the rewarded goal box was reversed and the rats had to acquire the reversal to the same criterion as the original position discrimination. This procedure was repeated until all rats had learned at least three reversals. Throughout the study rats were exposed to microwave radiation for 15 min following each day's training or else they were sham-exposed (factor 1). The exposure or sham-exposure was given either immediately or delayed (factor 2) until 4 hr had elapsed after training. Analysis of the data in this 2 x 2 factorial experiment failed to reveal any learning/memory disrupting effects of the post-trial microwave exposure.

6850 ANALYSIS OF DOSE-RESPONSE SYNERGY OF MICROWAVES AND

CHLORODIAZEPOXIDE EFFECTS ON FIXED-INTERVAL BEHAVIOR IN THE RAT (MEETING ABSTRACT). (Eng.) Lovely, R. H. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352); Lundstrom, D. L.; Phillips, R. D. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 30; 1980 (no refs).

Rats were maintained at 80% of their ad-lib body wt and trained to press a bar for food reward on a fixed-interval (1-min) schedule of reinforcement. Subsequently, the rats were adapted to a restraint holder in an anechoic chamber for 30 min/day prior to working for food. After adaptation to the restraint holder a dose-response curve was generated for each rat illustrating the effect of chlorodiazepoxide on fixed-interval behavior. These data were compared to those obtained by combining microwave exposure (2.88 GHz, 300 pulses/sec, 3.0- μ sec pulse width, average incident power density 1 mW/cm²) and administration of chlorodiazepoxide. The results of this synergistic pairing on the rats' fixed-interval performance will be compared to results obtained from similar studies carried out in other laboratories.

6851 BEHAVIORAL CHANGES DURING LONG-TERM MICROWAVE IRRADIATION (MEETING ABSTRACT). (Eng.) Lebovitz, R. M. (Dept. Physiology, Univ. Texas Health Science Center, Dallas, TX). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 30; 1980 (no refs).

A specialized laboratory was established to study the effects of long-term microwave exposure on complex behavior in the rat. This laboratory consisted of a computer-controlled behavioral array within which rats could be individually exposed to stable and closely regulated levels of microwave radiation (MWR) while simultaneously performing operant behavioral tasks of varying complexity. Using a paradigm designed to measure bar-press performance for food reward as well as uncued motor activity (exploratory bar-press), rats were exposed to pulse modulated MWR (1.3 GHz, 1- μ sec pulse width at 600 pulses/sec) for periods of up to 10 wk. At an average dose rate of 1.5 mW/g, there were no discernable differences in the food reward mediated bar-press behavior of the irradiated versus the nonirradiated rats. Exploratory bar-press behavior was more variable in the irradiated group but was not significantly different overall from the controls. At 3.6 mW/g, there was no apparent effect of the irradiation on food mediated bar-press behavior. Exploratory bar-press behavior, however, was transiently reduced in the irradiated rats. At 6.8 mW/g, there was a slight reduction in reward mediated bar-press behavior in the irradiated rats accompanied by a much larger reduction in exploratory bar-press

behavior. The differences between control and irradiated groups tended to diminish with continued exposure. The author concludes that actively rewarded operant behavior can be highly resistant to change by levels of MWR exposure that are metabolically significant while parallel, operantly unrewarded behavior can show major interruption.

6852 HEALTH CONDITION OF WORKERS EXPOSED TO LONG-TERM RADIO FREQUENCY RADIATION (0.3-30 MHz) (MEETING ABSTRACT). (Eng.) Pazderova-Vejlupkova, J. (Dept. Occupational Diseases, University Hosp., Vysehradská 49, 128 21 Prague 2, Czechoslovakia); Lukas, E.; Nemcova, M.; Dvorak, J.; Pickova, J.; Bryndova, V. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 31; 1980 (no refs).

Ninety-five persons occupationally exposed for more than 10 yr to radio frequency radiation (0.3-30 MHz) in radio transmitter stations were carefully examined during their hospitalization. The following examinations were performed: medical, ophthalmologic, neurologic, psychiatric, psychologic, gynecologic in women, chest x-rays, electrocardiogram, urine analysis, 17-ketosteroids/24 hr urine, blood sedimentation rate, blood count, protein-bound iodine, blood proteins and their fractions, plasma lipoproteins (electrophoresis), glucose tolerance test, and betacarotene. In the serum, total lipids and cholesterol, bilirubin, thymol turbidity, glutamic pyruvic and glutamic oxaloacetic transaminases, lactic dehydrogenases, urea nitrogen, creatinine, sodium, potassium, calcium, chloride, alkaline phosphatase, and iron were analyzed. Intensity of the electromagnetic field was repeatedly measured. In some working places the intensity exceeded values permissible in Poland (50 V/m for 8 hr/day). The results of examinations were compared with controls and statistically evaluated. No signs of damage due to electromagnetic radiation were found in the examined persons.

6853 BIOELECTRICAL BRAIN ACTIVITY IN EMPLOYEES EXPOSED TO VARIOUS FREQUENCY ELECTROMAGNETIC FIELD (MEETING ABSTRACT). (Eng.) Bielski, J. (Dept. Hygiene and Work Safety, Agricultural Univ., Poznan, Poland); Sawinska, A.; Pianowska, J. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 31; 1980 (no refs).

Bioelectrical activity of the brain of employees operating radio and television installations (range of 3.000-7.000 MHz frequency microwaves and 0.1-2.0 W/m² power density) was analyzed by electroencephalogram (EEG). In many employees

neurasthenic syndromes with vegetative disturbances appeared. Anomalous EEGs were found in 28%. EEGs with low voltage surface leads of alpha or flat type and deep leads with single, short series of slow theta waves were recorded. Industrial employees exposed to an electromagnetic field of 7-30 MHz frequency and 30-200 V/m intensity also demonstrated neurasthenic syndromes with vegetative disturbances but with a greater intensity than in the former group. Anomalous EEGs were found in 69%. EEGs with low voltage or flat surface leads and high voltage deep leads with numerous series of slow theta waves and with single sharp waves ("spikes") were recorded. This study demonstrated that an electromagnetic field, even when it is not very intense, adversely affects general health conditions, in particular the bioelectrical activity of the brain. The greater number of anomalous EEGs and the increased intensity of EEG changes observed in industrial workers as compared to radio and television employees may indicate a more harmful influence on brain activity of longer waves characterized by lower frequency as compared to microwaves of very high frequency.

6854 CATARACTS FOLLOWING USE OF CATHODE RAY TUBE DISPLAYS (MEETING ABSTRACT). (Eng.) Zaret, M. M. (Zaret Foundation, 1230 Post Rd., Scarsdale, NY 10583). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 32; 1980 (no refs).

The development of cataracts, in relation to the use of cathode ray tube generated displays, that exhibit characteristics resembling nonionizing radiation injury is reviewed. Case reports are presented that clearly indicate (1) that both cumulative and additive effects occur, (2) that there is a time-related delay before the appearance of lens pathology, and (3) that the cataractogenesis, if discovered and recognized at any early stage, may become arrested in forme fruste by protection from continuing exposure. Case studies are presented that led to the direct implication of previously unsuspected nonionizing radiation wavebands at etiologic or contributory cataractogenic factors. Examples of epidemiologic investigations are provided. The significance of clustering is detailed. An analysis is made of the spectral emissions from typical cathode ray tube displays under normal and malfunction operating conditions. The rationale for determining, beyond any reasonable doubt, the irrelevance of applying conventional nonionizing radiation health-safety criteria is discussed. Finally, a detailed pragmatic methodology whereby this problem can be investigated epidemiologically and ultimately solved is presented.

6855 BIOLOGICAL EFFECTS OF CHRONIC EXPOSURE OF MINIATURE SWINE TO 60 Hz

ELECTRIC FIELDS (MEETING ABSTRACT). (Eng.) Phillips, R. D. (Biology Dept., Battelle Pacific Northwest Lab., Richland, WA 99352). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 32; 1980 (no refs).

The biologic effects of long-term (2 yr), chronic (20 hr/day, 7 days/wk) exposure to 60-Hz electric fields (30 kV/m) on two filial generations of miniature swine are being studied. Fifty-one females (F₀ population) were started on exposure at 18 mo of age. After 4 mo of exposure, the F₀ gilts were bred with unexposed boars to produce offspring (F₁) that were exposed from conception through adulthood (24 mo). Prior to and throughout the exposure period, the animals are subjected to routine clinical examinations and to a battery of tests to assess for effects of exposure. In addition, data were collected on pregnant sows and their 100-day-old fetuses for teratologic, neurophysiologic, and clinical pathologic examinations. No adverse biologic effects were observed in reproduction, growth, development, hematology, serum chemistry, immunology, cytogenetics, or mortality in the F₀ during the first 12 mo of exposure or in the F₁ during the first 6 mo of exposure. Significant changes were observed among exposed animals in behavior (open-field test and 7-choice maze) and in one neurophysiologic test (synaptic transmission). The behavioral and neurophysiologic effects may reflect the animals response to chronic stimulation by electric-field exposure.

6856 NON-LINEARLY LOADED INSULATED PROBES FOR THE MEASUREMENT OF ELECTRIC FIELD DISTRIBUTION IN BIOLOGIC MEDIA (MEETING ABSTRACT). (Eng.) Bozzetti, M (Facoltà di Ingegneria, Istituto Elettrotecnico, Università Degli Studi di Bari, Via re David, 200, 70125 Bari, Italy); Corsi, F.; DeLeo, R. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 34; 1980 (no refs).

An analysis of the behavior of a nonlinearly loaded antenna immersed in a biologic medium and illuminated by an electromagnetic field source external to the body operating at two different ultrahigh frequencies was performed. The Volterra series approach was used to evaluate the power scattered by the antenna at some close intermodulation frequency components. A sensitivity study was performed to optimize the design of the probe and the whole system. The results showed that these nonlinearly loaded probes are suitable for electromagnetic field measurements in biologic bodies. The main characteristics exhibited by this measurement system are: 1) a sensitivity in the electric field measurement of 1 V/m, 2) linear dependence between local electric field and power ratio between two appropriate spectral lines, 3) implantation depth of

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the probe up to about 10 cm at 960 MHz, and 4) independence of the probe response on the biologic tissue dielectric characteristics.

6857 MICROWAVES DOSIMETER DESTINED TO SAFETY PROTECTION AGAINST RADIATION (MEETING ABSTRACT). (Eng.) Pellissier, J. P. (Groupe Effets Biologiques des Micro-ondes, Lyon, France); Pre, A.; Deschaux, P.; Santini, R. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 34; 1980 (no refs).

Different forms of an appliance that measure the quantity of energy, expressed by J/cm^2 , that is absorbed by an irradiated body are described. The simplest model has its own power source and can be fixed to the small pocket of a jacket. Another model has in addition an optical and sonorous alarm. It is also able to order the switch-off of a relay when the density of microwaves power, at the appliance level, exceeds a preregulated threshold.

6858 PENETRATION DEPTH AND SPATIAL RESOLUTION OF ATRAUMATIC PROBES FOR MICROWAVES (MEETING ABSTRACT). (Eng.) Nguyen, D. D. (Centre Hyperfréquences et Semiconducteurs, No. 287, LA-CNRS, 59655 Villeneuve D'Ascq cedex, France); Robillar, M.; Chive, M.; Leroy, Y.; Audet, J.; Bolomey, J. C.; Pichot, C. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 35; 1980 (no refs).

The electrical properties of probes that are used for biomedical applications (e.g., microwave thermography, local hyperthermia) that have an open rectangular waveguide filled with a dielectric are described. Numeric methods were used to calculate the reflection coefficient and the near field configuration in lossy materials. The results were compared with experimental measurements and with analytical expressions. Systematic studies, in the frequency range 1-9 GHz, showed that the matching of the probe and the penetration depth depend not only on the characteristics of the living tissue but also on those of the probe.

6859 THERMAL IMAGING AT 9 GHz MICROWAVES (MEETING ABSTRACT). (Eng.) Mamouni, A. (Centre Hyperfréquences et Semiconducteurs, No. 287, LA-CNRS, 59655 Villeneuve D'Ascq cedex, France); Sozanski, J. P.; Leroy, Y.; Moschetto, Y. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June*

30-July 4, 1980 in Jouy en Josas, France. p. 35; 1980 (no refs).

An original system of microwave thermal imaging is described and the results of preliminary tests are presented.

6860 THERMAL EQUIVALENT OF MICROWAVES IN LIVING CELLS (MEETING ABSTRACT). (Eng.) Dardalhon, M. (Section de Biologie, Institut Curie, 26 rue d'Ulm, 75231 Paris, France); Berteaud, A. J.; Averbeck, D. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 36; 1980 (no refs).

The global temperature of the cellular system after treatment with microwaves was studied in *Saccharomyces cervisiae* zygotes. Two haploid strains of different mating types that gave rise to stable heterozygote diploid cells were used. The irradiations were performed at frequencies 9.4 GHz, 17 GHz, and 73 GHz using power levels between 1 and 60 mW/cm². Estimations of equivalent temperatures were achieved by comparing the results to those obtained after conventional heating. The results showed that a power density of 10 mW/cm² was equivalent to a global rise in temperature of the cells by 0.5-1°C, depending on the frequency used. The heating produced goes through a maximum at 17 GHz (about 1°C at 10 mW/cm²), indicating that it is essentially due to the dielectric absorption of the microwaves by free or loosely bound water molecules in the cytoplasm. This approach makes it possible to obtain a quantitative, precise, and reproducible estimation of a thermal equivalent of microwaves at the unicellular level.

6861 NEW NON-INTERFERING THERMOMETRIC NEEDLE PROBES FOR IN SITU THERMAL DOSIMETRY DURING ELECTROMAGNETIC IRRADIATION PRODUCING HYPERTHERMIA (MEETING ABSTRACT). (Eng.) Samsel, M. (Laboratoire de Thermologie Biomedicale, Faculte de Medecine, Universite Louis Pasteur, 11 rue Humann, 67085 Strasbourg cedex, France); Gautherie, M. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 36; 1980 (no refs).

Various prototypes of needle thermometric probes, noninterfering with hyper- or radio frequency electromagnetic waves, were designed to control and accurately monitor deep tissue temperature during local electromagnetic hyperthermia for cancer treatment. The probes consist essentially of optical fibers and cholesteric liquid crystals; they are original with respect to the nature of the liquid crystals and

method used to measure temperature, and they are inexpensive and disposable. Investigations have been carried out on phantoms, postoperative specimens, and *in vivo* on patients, to evaluate the characteristics and reliability of the probes and to specify conditions for their clinical use.

6862 FIELD INTERACTION WITH NERVE- AND MUSCLE CELLS WITHIN 1 Hz AND 30 MHz (MEETING ABSTRACT). (Eng.) Bernhardt, J. H. (Institut für Radiologie, Universität Erlangen, Nürnberg, W. Germany). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 37, 1980 (no refs).

By using several biophysical approximations and considering man as spherical or spheroidal homogeneous model, limiting order-of-magnitude values for external electric and magnetic field strengths that may be hazardous for human beings were calculated. Danger may occur by excitation processes below 10 kHz for field strengths exceeding these limiting values; for frequencies larger than 10 kHz, thermal effects are predominant before excitation occurs. This critical frequency increases to about 50 to 100 kHz for single pulses. The external electric field strength necessary for causing action potential in the central nervous system exceeds by far the corona forming level. Furthermore, by comparing the electrically and magnetically induced currents with the natural currents in man caused by brain and heart electrical activity, a "lower boundary line" can be estimated. Direct effects on the central nervous system from electric or magnetic field strengths that under-cut this boundary line may be excluded. Other mechanisms may be responsible for demonstrated biologic effects.

6863 THERMIC REPARTITION AT PROXIMITY OF A SPHERICAL HOT SPOT SITUATED IN A CYLINDRICAL PHANTOM (MEETING ABSTRACT). (Eng.) Ducourtieux, J. P. (Laboratoire des Radiations Ionisantes A, UER des Sciences, 87060 Limoges cedex, France); Bonfanti, J. C.; Bernard, M. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 37, 1980 (no refs).

Temperature distribution after microwave hyperthermia of a spherical hot spot situated in the center of a cylindrical phantom model was studied. The cylindrical phantom was constructed to simulate a cylindrical anatomic zone with the hot spot simulating a deep cancerous tumor. Temperature repartition was achieved when the medium was not perfused. Theoretical calculation was confirmed by experimentation.

6864 COMPARATIVE STUDIES OF HYPERFREQUENCY APPLICATORS (2,450 MHz, 434 MHz) ON PHANTOMS AND POST-OPERATIVE SPECIMENS, WITH A VIEW TO USING MICROWAVE HYPERTHERMIA FOR CANCER TREATMENT (MEETING ABSTRACT). (Eng.) Guerquin-Kern, J. L. (Faculté de Médecine, Laboratoire de Thermologie Biomedicale, 11 rue Humann, 67085 Strasbourg cedex, France); Samsel, M.; Palas, L.; Gautherie, M. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 38, 1980 (no refs).

The thermal effects of electromagnetic waves on biologic tissues have been simulated using two different physical models: 1) on excised animal tissues and postoperative specimens (e.g., after mastectomy) and 2) on original phantoms made of transparent gels and resins with known dielectric and thermal properties corresponding to those of biologic tissues. The deep thermal pattern was measured in the specimens with an infrared camera just after microwave radiation and in the phantoms with real-time display during electromagnetic irradiation by films of cholesteric liquid crystals. The results obtained with various prototypes of applicators working at 2.450 MHz and 434 MHz demonstrated the importance of the geometric configuration of the applicator and the necessity of a surface cooling system when hyperthermia is localized within a given target volume.

6865 THEORETICAL AND EXPERIMENTAL CONSIDERATIONS OF A RADIO FREQUENCY SYSTEM FOR TISSUE HEATING (MEETING ABSTRACT). (Eng.) Hand, J. W. (MRC Cyclotron Unit, Hammersmith Hosp., Du Cane Rd., London W12 OHS, England); Ledda, J. L.; Cobbett, F. C.; Hopewell, J. W. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*, p. 38, 1980 (no refs).

The induction of heating (27.12 MHz) in tissues was studied with the aid of mathematic models. Circular "pancake" coils and rectangular coils were considered and particular interest was given to such variables as the dimensions of the coils and their distance from the tissues. A method of reducing the toroidal nature of the heating patterns induced by coils of circular geometry was presented. The problems associated with the measurement of temperature during electromagnetically-induced hyperthermia may be reduced by using very fine thermocouples while the fields are turned off. A controller that periodically up-dates information on temperature in the absence of electromagnetic heating fields was developed. It can be programmed to control a number of applicators (induction coils, microwave applicators, etc.) to maintain tissue temperature within ± 0.1 C of a preset value. The

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system was tested in phantoms and anesthetized pigs and relevant results are presented.

6866 THEORETICAL SIMULATION OF ELECTROMAGNETIC WAVE PENETRATION AND ITS APPLICATION (MEETING ABSTRACT). (Eng.) Priou, A. (ONERA-CERT-DERMO, B.P. No. 4025, 31055 Toulouse cedex, France); Fournet-Favas, C.; Gimonet, E.; Guerquin-Kern, J. L.; Samsel, M.; Gautherie, M. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 39; 1980 (no refs).

Theoretical simulations of the depth of penetration of electromagnetic waves at 434 MHz (free wavelength 69 cm) were studied with respect to the surface conditions (with or without cooling) and to the number of applicators (1 or 2 or crossed applicators). Experimental studies were also conducted to design compact and low-weight applicators and to improve the coupling of electromagnetic waves to the material to be treated.

6867 IRRADIATION SYSTEMS FOR STUDYING NONTHERMAL BIOLOGICAL EFFECTS OF HIGH FREQUENCY MICROWAVES (MEETING ABSTRACT). (Eng.) Keilmann, F. (Max-Planck-Institut fur Festkorperforschung, 7000 Stuttgart 80, W. Germany); Grundler, W. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 39; 1980 (no refs).

The control of irradiation frequency and intensity (the latter with emphasis on standing waves) was discussed. Thermal transport analysis revealed that a moderate irradiation intensity (10 mW/cm^2) did not lead to microthermal effects inside living cells (i.e., cannot noticeably raise the temperature or generate a significant temperature gradient), provided these cells are suspended in water (or agar) that is held at a constant temperature. At high frequencies microwave absorption in water is so strong that to produce a homogeneous irradiation intensity, the sample must be thin in at least one dimension. A thin planar layer is a practical design, where one surface can be used for thermostating by heat conduction through a suitable solid and the other surface can be designed, e.g., by use of a semipermeable membrane, to accomodate various biologic requirements like sterilization, filling, nutrition, and perspiration.

6868 TEMPERATURE INDEPENDENT EFFECTS OF MICROWAVE EXPOSURE ON CHINESE HAMSTER CELLS (MEETING ABSTRACT). (Eng.) Subjeck, J. R. (Roswell Park Memorial Inst., Buffalo, NY 14263); Sciandra, J.; Johnson, R. J.;

Drechsel, R.; Kowal, H. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 40; 1980 (no refs).

V-79 chinese hamster cells were exposed to low temperature hyperthermia by heating the cells in either a water bath or by 915-MHz microwave radiation. In initial studies, cells were seeded in a 35-mm petri dish that was positioned at the end of a TE₁₀ energized, open ended waveguide. The bottom of the dish, to which the cells were attached, was in contact with a circulating water bath ($\pm 0.1 \text{ C}$). At approximately 600 mW/cm^2 of incident power and a temperature of 41 C , no difference was observed in cell survival when exposed cells were compared with control cells (0-W) at 41 C . At approximately 2.000 mW/cm^2 , however, a statistically significant decrease in survival was observed, even though the cell temperature was maintained at 41 C . Because incident power densities in this system could only be approximated and because the site and external position of the petri dish introduced the possibility of unknown reflections, a second exposure system was designed. In this system, cells were placed inside a saline-filled waveguide using a 50-lambda micropipette. The saline was circulated to control temperature. The micropipette was too small to interfere with the propagated TE₁₀ mode. Field attenuation between antenna and specimen were accurately calculated. The results obtained from this system will be compared with those obtained in the initial studies.

6869 MICROWAVE HYPERTHERMIA DELIVERY SYSTEMS (MEETING ABSTRACT). (Eng.) Kowal, H. (Roswell Park Memorial Inst., Buffalo, NY 14263); Kantor, G.; Johnson, R. J.; Subjeck, J. R. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 40; 1980 (no refs).

Hyperthermia produced by 915-MHz and 434-MHz microwave sources was used to treat *in vivo* tumors. Various types of applicators were developed to effectively direct the radio frequency (RF) beam to a specific treatment area. Direct contact, air cooled, dielectric filled waveguides and infinite plane directional antennas were the two basic designs that met the requirements of RF beam containment and patient treatment. The development, applicator efficiency, microwave power requirements, and energy deposition in tissue will be discussed as a function of 915 and 434 MHz.

6870 MICROWAVE HEATING FOR BIOLOGICAL SAMPLES (MEETING ABSTRACT). (Eng.) Checcucci, A. (Istituto Ricerca

Onde Electromagnetiche, CNR, Firenze, Italy); Paoletti, P. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 41; 1980 (no refs).

Experiments on microwave heating of fresh frozen plasma, banked plasma, cryoprecipitates, and hemodiagnostic sera were conducted to compare the biologic reliability of microwave heating with that of traditional warming techniques. A microwave bridge and a commercial microwave oven were used as warmers. Total protein and electrophoretic patterns of the selected hemoderivatives were analyzed, as well as some coagulating factors and agglutination reactions. The results confirmed the reliability of the microwave heating.

6871 COMPARATIVE STUDY OF MICROWAVE DIATHERMY AT 434 MHz, 915 MHz, AND 2,450 MHz (MEETING ABSTRACT). (Eng.) Kantor, G. (Div. Electronic Products, BRH, FDA, Rockville, MD 20857); Witters, D. M. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 41; 1980 (no refs).

Heating patterns induced by diathermy in planar phantoms and associated stray radiation were compared at 434 MHz, 915 MHz, and 2,450 MHz. Three circular applicators with aperture diameters of about 15 cm were selected for study. The 915-MHz and the 2,450-MHz applicators are direct contact BRH prototypes, the former with an annular choke and the latter with an annular choke covered with a 2.5-cm thick absorber to minimize leakage radiation. The 434-MHz applicator is commercially available. The heating patterns were obtained by placing the applicators symmetrically on top of a planar phantom of simulated fat and muscle tissues. The 434-MHz diathermy evaluation was hindered by the extremely low rate of energy deposition. The measurements showed that the 434-MHz patterns were broader and the depth of penetration into muscle tissue was somewhat greater than for 915 MHz and 2,450 MHz. The leakage radiation at 5 cm from the applicator phantom boundary, when delivering 235 W/kg to simulated muscle, was considerably less than 10 mW/cm² for the 915-MHz and 2,450-MHz applicators. Leakage measurements for the 434-MHz applicator indicated that this design needs to be modified in order not to greatly exceed 10 mW/cm² of leakage for high power diathermy settings.

6872 FORMATION OF METHIONINE DERIVATES DURING MICROWAVES HEATING. NUTRITIONAL INTEREST (MEETING

ABSTRACT). (Eng.) Airaudo, C. B. (Laboratoire de Bromatologie, Faculte de Pharmacie, Dietetique et Analyse Appliquee a l'Expertise, 27 bd. Jean Moulin, 13385 Marseille cedex 4, France); Gayte-Sorvier, A. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 42; 1980 (no refs).

The effects of microwave heating (of various exposure durations, 0-20 min) and its interaction with the effects of dry or liquid medium and pH (0-14) on the behavior of a methionine and glucose solution were studied. The results were compared with those produced by microwave heating of methionine or glucose alone and with the results obtained by conventional heating of the same solutions. The formation of methionine sulfoxides and of 1-amino-deoxy-2-ketose (methionine glucose), but not of methionine sulfone, was observed. The formation of methionine glucose is tightly bound to the disappearance of methionine; extreme pH conditions may lead to the complete loss of the amino acid. Residual rates of the initial nutrients were presented, and the nutritional consequences of the observed phenomenon were discussed. It is concluded that conventional microwave heating does not seem to involve more important losses of methionine and glucose than conventional heating.

6873 THERMAL IMAGING USING MICROWAVE RADIOMETRIC SYSTEMS APPLIED TO DETECTION AND PROGNOSIS OF BREAST, CEREBRAL AND THYROID TUMORS (MEETING ABSTRACT). (Eng.) Gautherie, M. (Laboratoire de Thermologie Biomedicale, Faculte de Medecine, Universite Louis Pasteur, 11 rue Humann, 67085 Strasbourg, France); Moyses, B.; Leroy, Y.; Mammuni, A.; Moschetto, Y.; Sozanski, J. P. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 44; 1980 (no refs).

Various clinical investigations were carried out with an original, highly sensitive microwave radiometer operating at 9 GHz. This device allowed direct display of thermal profiles on an oscilloscope screen and the possible reconstruction of thermographic images. Three groups of patients with benign or malignant tumors were investigated: 1) breast tumors (comparison with mammography and echotomography), 2) cerebral tumors (comparison with computed axial tomographic scanner and arteriographic findings), and 3) thyroid tumors (comparison with scintigraphy and echotomography). Microwave thermography seemed to provide significant information on metabolism and thermal conditions of subcutaneous tumor tissue, especially where infrared thermography did not work e.g., cerebral tumors or deep-seated or *in situ* breast carcinomas.

6874 TEMPERATURE-TIME PROFILE IN RATS SUBJECTED TO SELECTIVE MICROWAVE IRRADIATION OF THE BRAIN (MEETING ABSTRACT). (Eng.) Lin, J. C. (Dept. Electrical Engineering, Wayne State Univ., Detroit, MI 48202); Lin, M. F. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 44; 1980 (no refs).

Real-time cortical and colonic temperature changes in rats irradiated for 20 min by a 2,450 MHz contact radiator at the head were measured. Microwaves were delivered to the radiator at 10- μ sec pulses, at pulse repetition rates of 25-500 parts/sec, and at energy rates of 1-5,000 mW, corresponding to incident power densities of 0.5-3,250 mW/cm². Lower power densities yielded a small cortical temperature increase below that for the body core whereas higher power densities produced a greater cortical temperature rise. Even at an incident power density as high as 3,250 mW/cm² (specific absorption rate of 260 mW/g in the brain), the cortical temperature increased by less than 3.0 C, while the colonic temperature rose by 0.5 C. The cortical temperature rose rapidly during the initial transient period of irradiation, but it became nonlinear and achieved a steady-state level around 39 C. It is concluded that the brain temperature was lowered by thermoregulatory processes involving blood circulation, temperature, and mass differences between the brain and the nonirradiated body of the anesthetized rat, and that the irradiated brain received significant protection from the nonirradiated body.

6875 WHOLE-BODY EXPOSURE IN THE NEAR ZONE OF HF ELECTROMAGNETIC FIELDS (MEETING ABSTRACT). (Eng.) Lin, J. C. (Dept. Electrical Engineering, Wayne State Univ., Detroit, MI 48202). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 45; 1980 (no refs).

The induced field and absorbed energy in a prolate spheroidal model of the human body and in a spherical model of the human head exposed to uniform near zone high frequency (HF) fields having different normalized field impedances are reported. The results showed that in the HF frequency region, the magnetically induced contribution to energy absorption was much larger than the contribution due to the external electric field. This was true even for field impedances of 0.77 kohms, where the ratio of external electric to magnetic field strengths was 100 to 1. The specific absorption rate (SAR) varied over four orders of magnitude for normalized impedances ranging from 0.1 to 100. The SAR decreased as the square of normalized impedance between 0.1 and 1.0 and it approached a baseline for normalized impedances greater than 10. These results imply that for a constant SAR, the required external field

strength with normalized impedances less than unity would be substantially less than that required of a field with normalized impedances greater than unity.

6876 INTERNAL DOSIMETRY OF THE CD1 MOUSE EXPOSED TO 2,450 MHZ RADIOPHREQUENCY (MEETING ABSTRACT). (Eng.) Kinn, J. B. (Bioengineering Branch, Experimental Biology Div., Health Effects Res. Lab., EPA, Research Triangle Park, NC 27711). In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 45; 1980 (no refs).

CD-1 mice were exposed to 2,450-MHz radio frequency radiation in an anechoic chamber and the absorption characteristics were determined. The whole-body specific absorption rate (SAR) was measured using twin-well calorimetry, and the internal partial-body SAR was measured using thermography and internal temperature probes. Analysis was made of 100 mice specimens. The energy distribution within the mouse specimen was averaged over specific areas, e.g., brain, abdomen, and hypothalamus. The relation between whole-body dose and internal dosimetry, hot spot location, and variability of dose due to orientation of animal and field were discussed.

6877 DETECTION OF INTRACRANIAL LESIONS WITH THE HELP OF MICROWAVE RADIOMETRY (MEETING ABSTRACT). (Eng.) Robert, J. (Laboratoire de Biophysique, 18, rue Lionneis, 54000 Nancy, France); Thouvenot, P.; Mamouni, A.; Leroy, Y. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 46; 1980 (no refs).

Microwave radiometry was applied to the detection of intracranial lesions in 16 patients, and the results were compared with those obtained by radiology, scintigraphy, and surgery. Three recently devised sensors were tested: a radiometer operating at 9 GHz and thermographs operating at 63.30 GHz and 11 GHz. Thermal repartition in intracranial lesions was determined in five normal subjects. Two menangiomas, three gliomas, and one metastasis resulted in hyperthermia. Hypothermia was observed in one frontal glioma, probably linked to perifocal edema. One deep glioma resulted in diffuse hyperthermia. Recent cerebral softening was observed to induce hyperthermia, whereas older softening did not introduce any thermal perturbation.

6878 LOCAL HYPERTHERMIA CONTROLLED BY MICROWAVE THERMOGRAPHY AT

2.5 GHz (MEETING ABSTRACT). (Eng.) Nguyen, D. D. (Centre Hyperfréquences et Semi-conducteurs, No. 287, LA-CNRS, Université de Lille, 59655 Villeneuve D'Ascq cedex, France); Chive, M.; Leroy, Y. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 46; 1980 (no refs).

A noninvasive microwave thermographic technique that permits simultaneous heating and temperature measurement by radiometry was designed and the feasibility of such a system was tested. Three methods were proposed: 1) an alternate process, for which switching was carried out to make a temperature measurement during the operation; 2) a simultaneous process that achieved the two operations at the same time; and 3) a sampling process that used pulsed signals. The problems encountered, mainly due to intermodulation effects, were solved, and a prototype was designed that operated at 2.5-GHz, with a 16-WCW power generator and a high sensitivity radiometer. The initial results obtained with this system for animal tissues are presented.

6879 MEASURING AND MODELING HUMAN ERYTHROCYTES BEHAVIOUR AT MICROWAVE FREQUENCIES (MEETING ABSTRACT). (Eng.) Bianco, B. (Laboratorio per i Circuiti Elettronici, CNR, Genova, Italy); Drago, G. P.; Marchesi, M.; Martini, C.; Morando, M.; Morgavi, G.; Ridella, S.; Mela, G. S. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 47; 1980 (no refs).

Results of microwave spectroscopy of human blood are presented. With the aid of a recently developed accurate measurement technique, complex dielectric constants of several mixtures of erythrocytes and plasma (in various concentrations) obtained from healthy male volunteers were measured, in the frequency range of 100-2,000 MHz. The measured values were compared with those obtained with a blood model (i.e., a mixture of saline solution [plasma] and cells, in turn composed of mixtures of hemoglobin ellipsoids and another solution). The percent of water bound to hemoglobin, its relaxation frequency, and the normality of the saline solution of cytoplasm were also derived, through an optimization procedure. The results were in reasonable agreement with those obtained by other techniques. The results of an error analysis are also presented.

6880 APPLICATION OF TIME DOMAIN REFLECTROMETRY TO THE STUDY OF DIELECTRIC PROPERTIES OF BIOLOGICAL SUBSTANCES (MEETING ABSTRACT). (Eng.) Bottreau, A. (Laboratoire de Spectrométrie Tem-

porelle et Fréquentielle, Université de Bordeaux, Bordeaux, France); Bose, T. K. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 47; 1980 (no refs).

A new probe to be used in conjunction with "time domain reflectrometry" (TDR) for the measurement of dielectric properties of biologic substances was developed. This probe allows dielectric measurements to be made both *in vivo* and *in vitro*. The time domain method permits precise determination of dielectric loss curve over a frequency range extending from 10 kHz to 10 GHz with a single measurement. The authors suggest that this probe will lead to important contributions in the area of cancer research, particularly in microwave heating.

6881 STUDY AND MODELING OF COAXIAL PROBES FOR THE PERMITTIVITY MEASUREMENT OF IN VIVO BIOLOGICAL SUBSTANCES IN MICROWAVES (MEETING ABSTRACT). (Eng.) Castelain, A. (Centre Hyperfréquences et Semi-conducteurs, No. 287, LA-CNRS, Université de Lille, 59655 Villeneuve D'Ascq cedex, France); Dujardin, B.; Bliot, F.; Robert, J.; Escanye, J. M. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 48; 1980 (no refs).

A more complete theoretical approach of microcoaxial probes allowing relatively easy numeric simulations is presented. Numeric results were obtained in a wide range of complex permittivity $\epsilon' - \epsilon''j$ ($2 < \epsilon' < 80$; $2 < \epsilon'' < 40$), indicating the contributions due to the geometric parameters, the frequency, and the electrical properties of the medium under study. Experimental results are presented, obtained on polar liquids with dielectric properties similar to those of biologic tissues and on mixtures used as phantoms in microwave hyperthermia studies. A generally good agreement was obtained between experimental and numeric results in a wide frequency range (1-12 GHz).

6882 CLINICAL USE OF HYPERTHERMIA WITH RADIATION (MEETING ABSTRACT). (Eng.) Johnson, R. (Roswell Park Memorial Inst., Buffalo, NY 14263); Krishnamsetty, R. M.; Yakar, D.; Subjeck, J.; Kowal, H.; Wojtas, F.; Clay, L.; Dannels, J. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 50; 1980 (no refs).

Eighty tumors were treated with radiation and hyperthermia since 1976 using three protocols. A toxicity protocol investigated the patient's tolerance to treat-

ment, including the incidence of thermal damage, thermal pain, and the tolerance of patients to immobilization for treatment. Clinical thermal distributions were obtained for 2.450, 915, and 434 MHz microwaves. A design with measurements of normal tissue and tumor temperature, pO_2 , and pH were assessed during hyperthermia. A second protocol involved treatment of patients with multiple, metastatic cutaneous lesions to investigate the effect of immediate and delayed postradiation hyperthermia in the 42-C range on the thermal enhancement ratio of tumor and normal tissue by assessing regrowth response. The results of this protocol are presented together with a discussion on the difficulties of obtaining adequate data from patients with advanced disease and multiple cutaneous metastases. The third protocol investigated in three groups of patients the tumor enhancement factor resulting from postradiation 43-C hyperthermia. The first group of patients had either two or more tumors within 4 cm of the skin that were multiple or large enough to be divided into control and experimental areas. The control areas were treated with 400 rad fractions 2x/wk to a total dose of 4,000-4,800 rads and the experimental areas were treated with the same dose followed by immediate postradiation hyperthermia with 915 or 434 MHz microwaves. Whenever possible, the heat was applied specifically to the tumor by either defining the heat field or by cooling the superficial skin. A second group of patients who had previous radiation and were unsuitable for surgery were given radiation together with postradiation heat. The responses obtained with 915 and 434 MHz heat and radiation as compared with radiation alone are presented.

6883 INFLUENCE OF HYPERHERMIA ON THE BLOOD FLOW IN A CHEMICALLY INDUCED RHABDOMYOSARCOMA OF THE C3H MOUSE (MEETING ABSTRACT). (Eng.) Robert, J. (Laboratoire de Biophysique, 18 rue Léonnois, 54000 Nancy, France); Escanye, J. M.; Thouvenot, P.; Marchal, C. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 50; 1980 (no refs).

Local blood flow was measured by radioactive xenon inhalation technique in C3H mice bearing rhabdomyosarcoma who were treated with local hyperthermia induced by microwaves at 432 MHz. Blood flow was studied near the tumor and tissue and before, during, and after the daily hyperthermia treatment. Hyperthermia resulted in increased blood flow near the tumor and muscle.

6884 FACTORS AFFECTING MICROWAVE-INDUCED DISRUPTION OF THE BLOOD BRAIN BARRIER (MEETING ABSTRACT). (Eng.) Sutton, C. H. (Sch. Medicine, Univ. Miami, Miami, FL); Balzano, Q. In: *Abstracts of the Proceedings of*

the Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France. p. 51; 1980 (no refs).

To determine the upper limits of time and temperature for microwave irradiation without concomitant damage to nervous tissue, selective heating of the rat head was produced by shielding the remainder of the body with Eccosorb. In initial studies, microwave radiation at 2.450 MHz was delivered with a type A applicator. The integrity of the blood-brain barrier was studied using horseradish peroxidase. Animals were injected intravenously with 1.8 mg/10 g body wt 30 min prior to sacrifice. Rats were studied at brain temperatures of 40, 42, or 45 C. In animals with normal body temperature (37 C), the blood-brain barrier was disrupted with several combinations of brain temperature elevation and duration. Efforts to duplicate these findings with a second applicator consisting of dielectric-loaded rectangular waveguide were unsuccessful. It was found that the initial rate of power deposition was lower, due to dielectric breakdown and increased power reflection. A third applicator was constructed, consisting of a corrugated waveguide that was dielectric-loaded. With this applicator, it was possible to disrupt blood-brain barrier integrity with the same combinations of time and temperature that had been established previously with the type A applicator. It is concluded that the high initial rate of energy deposition possible with the type A and corrugated waveguide applicators was required to disrupt blood-brain barrier integrity. These findings indicate that, in addition to the level and duration of brain temperature elevation, initial power deposition rate is important in producing barrier disruption.

6885 TREATMENT OF URINARY BLADDER CARCINOMA WITH LOCAL HIGH FREQUENCY HYPERHERMIA (MEETING ABSTRACT). (Eng.) Harzmann, R. (Dept. Urology, Univ. Tübingen, Calwerstrasse 7, D-7400 Tübingen, W. Germany); Bichler, K. H. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 51; 1980 (no refs).

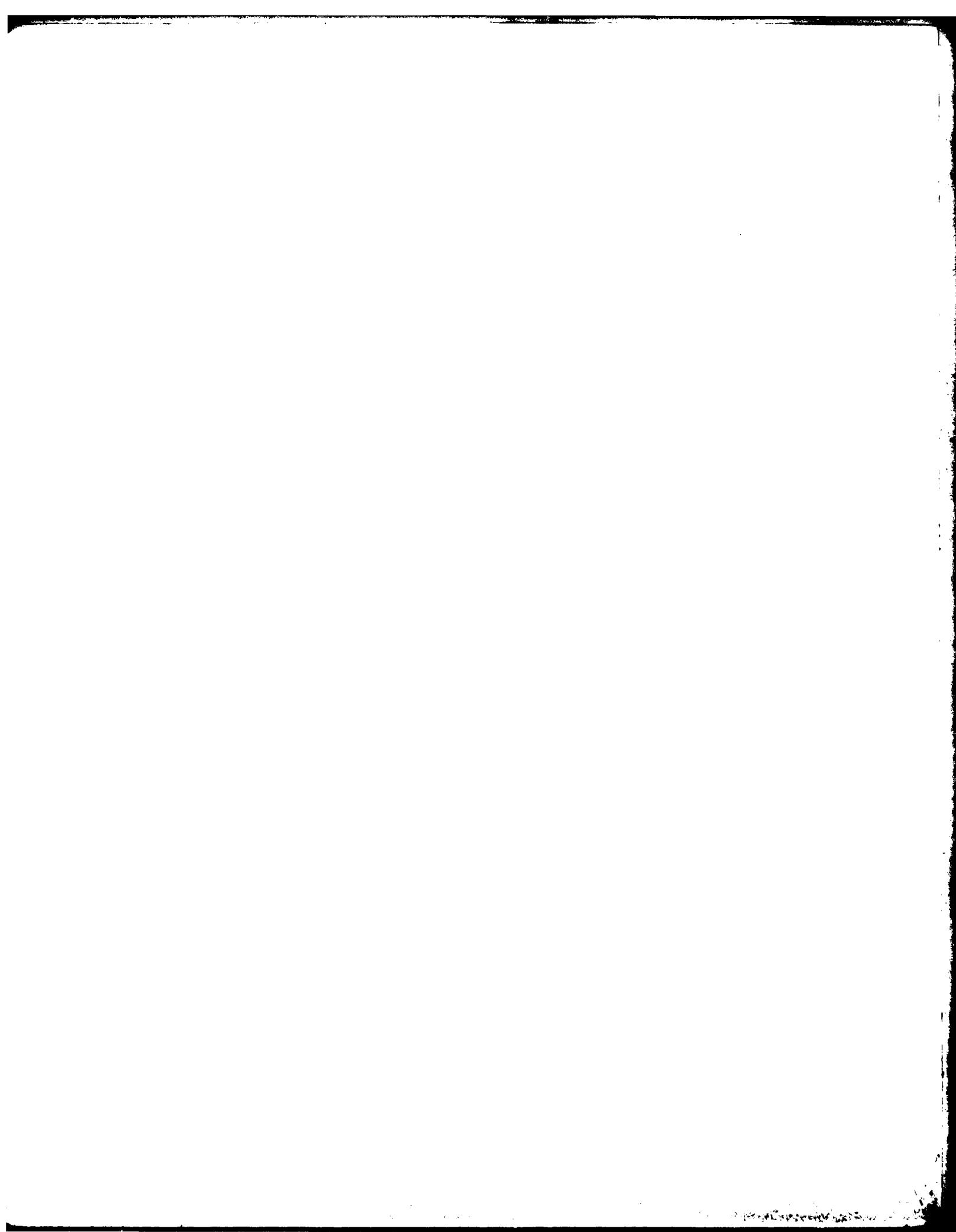
Techniques were sought for homogeneous hyperthermia of the bladder wall as well as information on the effects of hyperthermia on healthy and tumorous bladders in rabbits and dogs. Phantom trials led to the development of a transurethral high-frequency application technique. Healthy animal bladders showed a transient mucosal edema as a result of hyperthermia. Transurethrally hyperthermized (43 C) tumors in rabbit bladders necrotized subtotally, were smaller, and metastasized more seldom than untreated tumors. Local hyperthermia of invasive urothelial carcinoma in dog bladders led to tumor necrosis and stroma hyalinosis. Clinical use of transurethral local high-frequency hyperthermia in advanced, undifferentiated bladder carcinomas caused

tumor remission as a result of tumor necroses and stroma hyalinosis. Local hyperthermia is an adjuvant, palliative therapeutic technique.

6886 PRELIMINARY CLINICAL RESULTS OF LOCAL HYPERHERMIA BY RADIO-FREQUENCY WAVES IN THE TREATMENT OF VISCERAL TUMORS (MEETING ABSTRACT). (Eng.) Israel, L. (Centre Hospitalier Universitaire Avicenne, 93000 Bobigny, France); Besenval, M. In: *Abstracts of the Proceedings of the International Symposium on the Biologic Effects of Electromagnetic Waves held June 30-July 4, 1980 in Jouy en Josas, France*. p. 52; 1980 (no refs).

Forty-five patients with metastatic cancer not responsive or refractory to standard therapeutic procedures were treated by local hyperthermia using radio frequency waves (13.56 MHz). Each session lasted 45-

150 min and the total number of sessions ranged from four to nine over a 3-wk period. Temperatures in normal subcutaneous tissue were recorded by a thermocouple and reached 42-43 C. Intratumoral temperatures of 4 to 7.5 C above those of normal tissue were achieved. Temperatures recorded at the tumor periphery were equivalent to those of normal tissue. Of the 33 evaluable patients, 12 showed objective regression, 9 no change, and 12 progression. Regressions occurred 2 wk after the end of hyperthermia and were observed in 35% of the intra-abdominal tumors and 15% of the intrathoracic tumors. Stabilization of disease from 1 to 4.5 mo occurred in 23% of intrathoracic tumors and 21% of intra-abdominal tumors. Subjective improvement was noted even in patients who did not exhibit an objective response: i.e., alleviation of pain in 7/16, weight gain in 4/22, and improvement in specific tumor related symptoms in 5/8. The toxicity associated with the procedure was nil at 1-yr follow-up.



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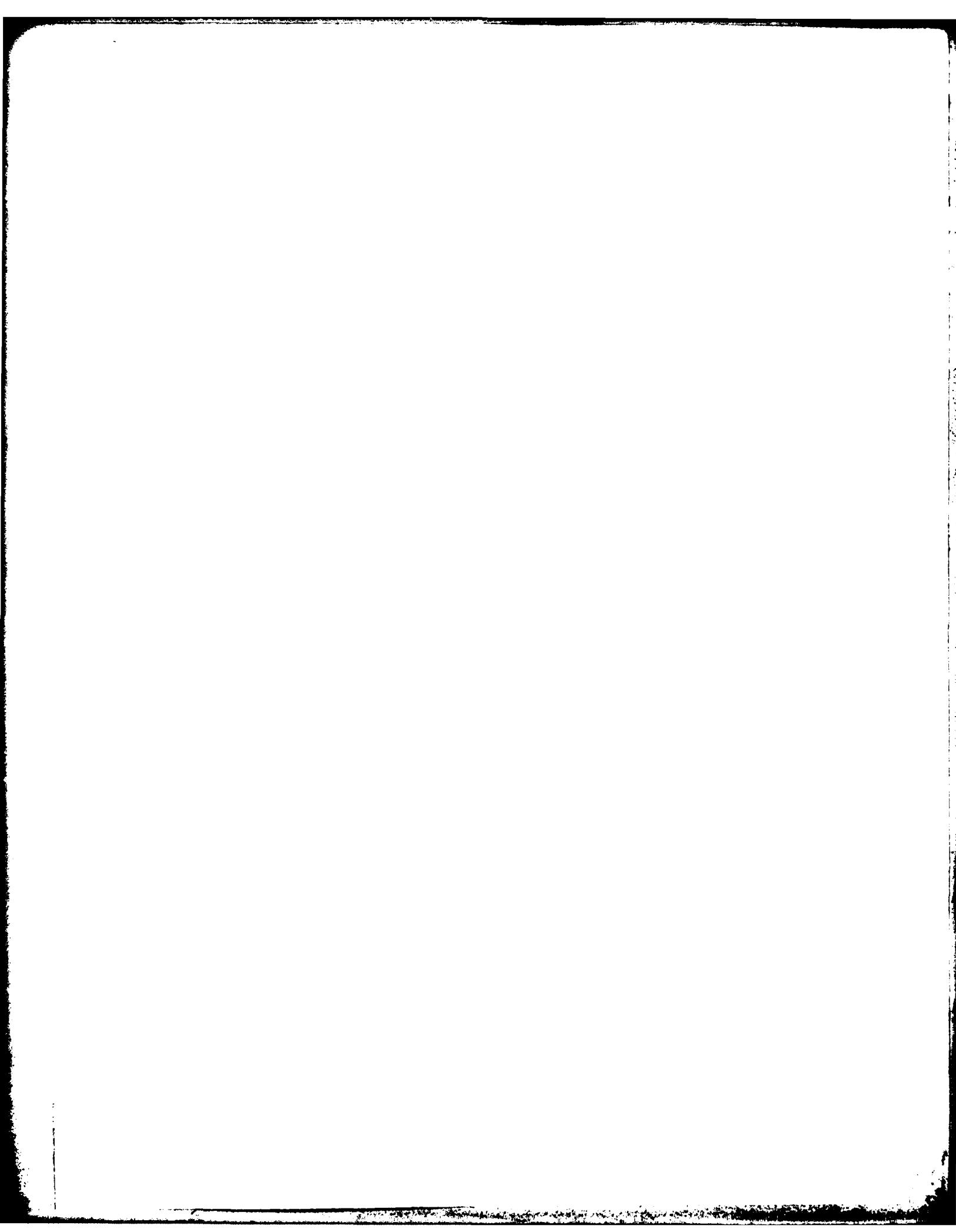
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12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

This quarterly digest presents current awareness information on the biological effects of nonionizing electromagnetic radiation (microwave and radio frequency) in the range of 0 Hz to 100 GHz. The effects of magnetic and electric fields (static and alternating) are also covered. Each issue contains abstracts of English and foreign current literature, summaries of ongoing research investigations, news items, and a directory of meetings and conferences.

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